Energy Audit Methods and Case Study of Electrical Utility

17 JAN. 2018

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Korea Energy Agency(KEA)

New & Renewable Energy Policy Division

KOREA ENERGY AGENCY

1. PUMP UTILITY

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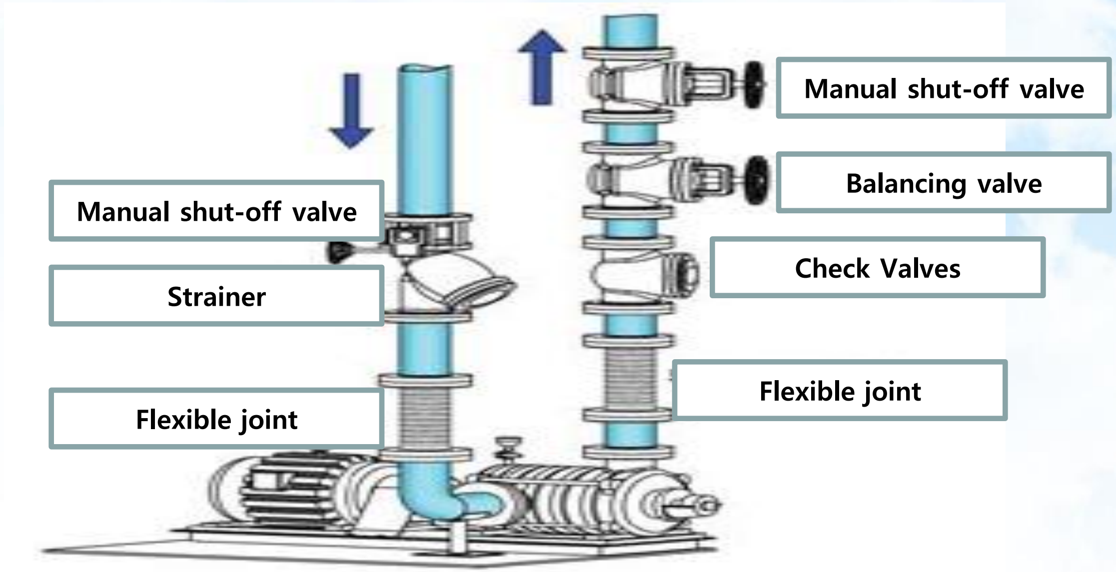
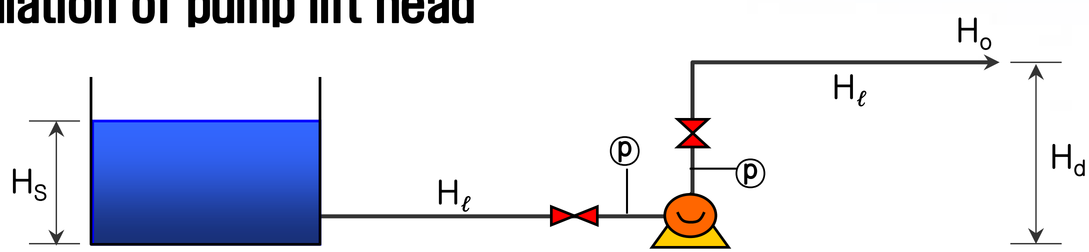
1. Pump Utility

A. Pump overview

◆ Composition of Pump



◆ Calculation of pump lift head



Needed Lift Head : $H = H_o + H_d + H_\ell - H_s$

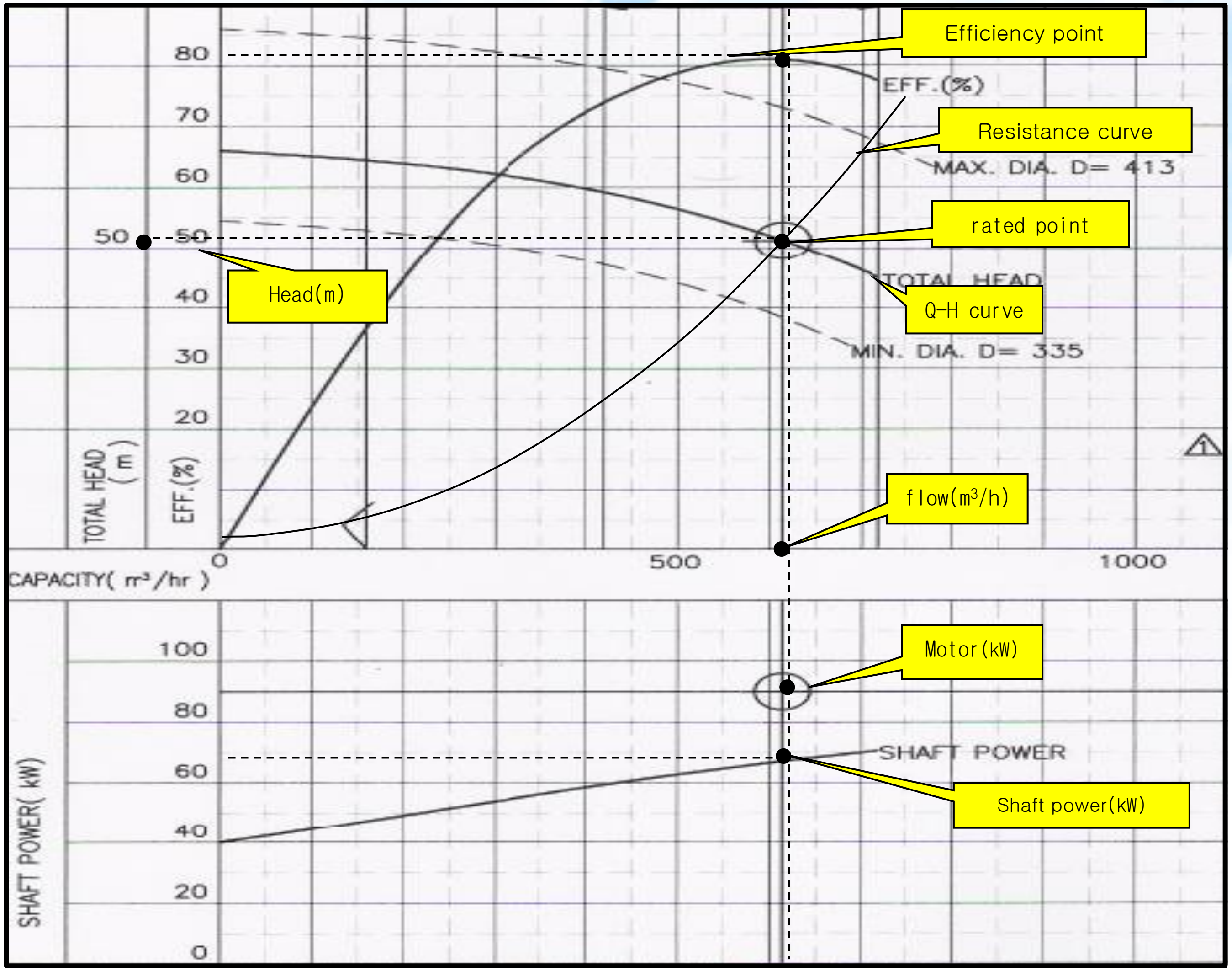
♦ Power equation of Pump

$$\text{Shaft power of Pump (kW)} = \frac{[\text{Lift Head(m)}] \times [\text{Flow(㎥/min)}]}{6.12 \times [\text{Pump efficiency(\%)}/100]}$$

N(revolutions per minute(RPM)) $\propto$ Flow(Q) , N^2(RPM) $\propto$ Lift Head(H) , P(Power) $\propto$ Flow(Q) x Lift Head(H)

☞ P(Power) $\propto$ RPM^3(N)

◆ Understand of Pump characteristic curve

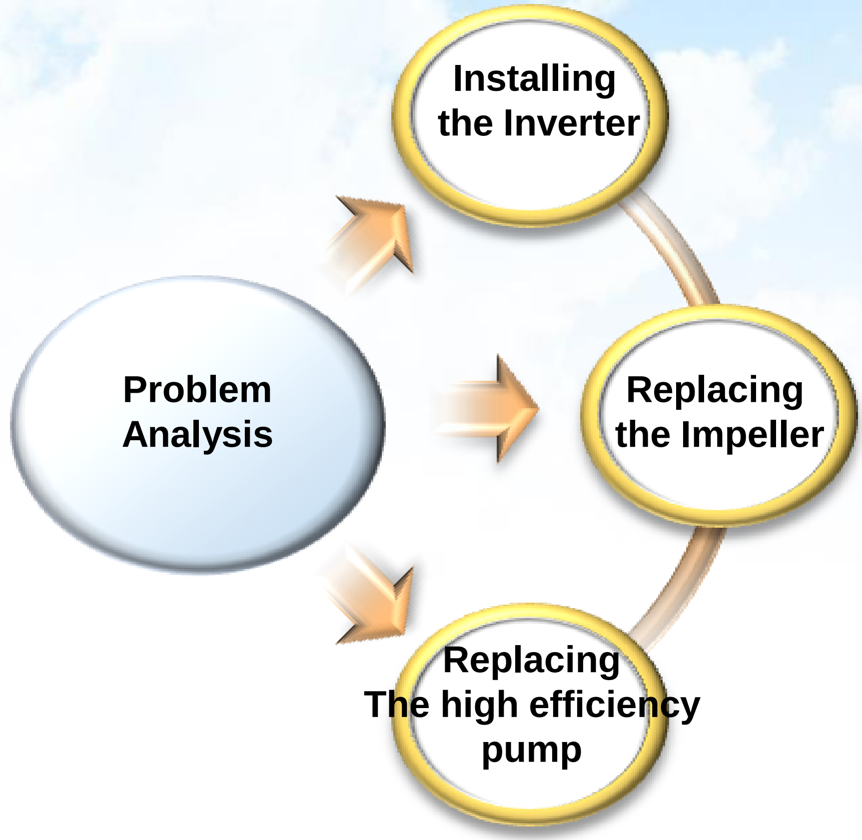


B. Pump Energy loss factor and improvement

ENERGY LOSS FACTOR

- Pressure(Head) loss
- Flow loss
- Loss of pump efficiency
- Load fluctuations
- Excessive capacity

IMPROVEMENT



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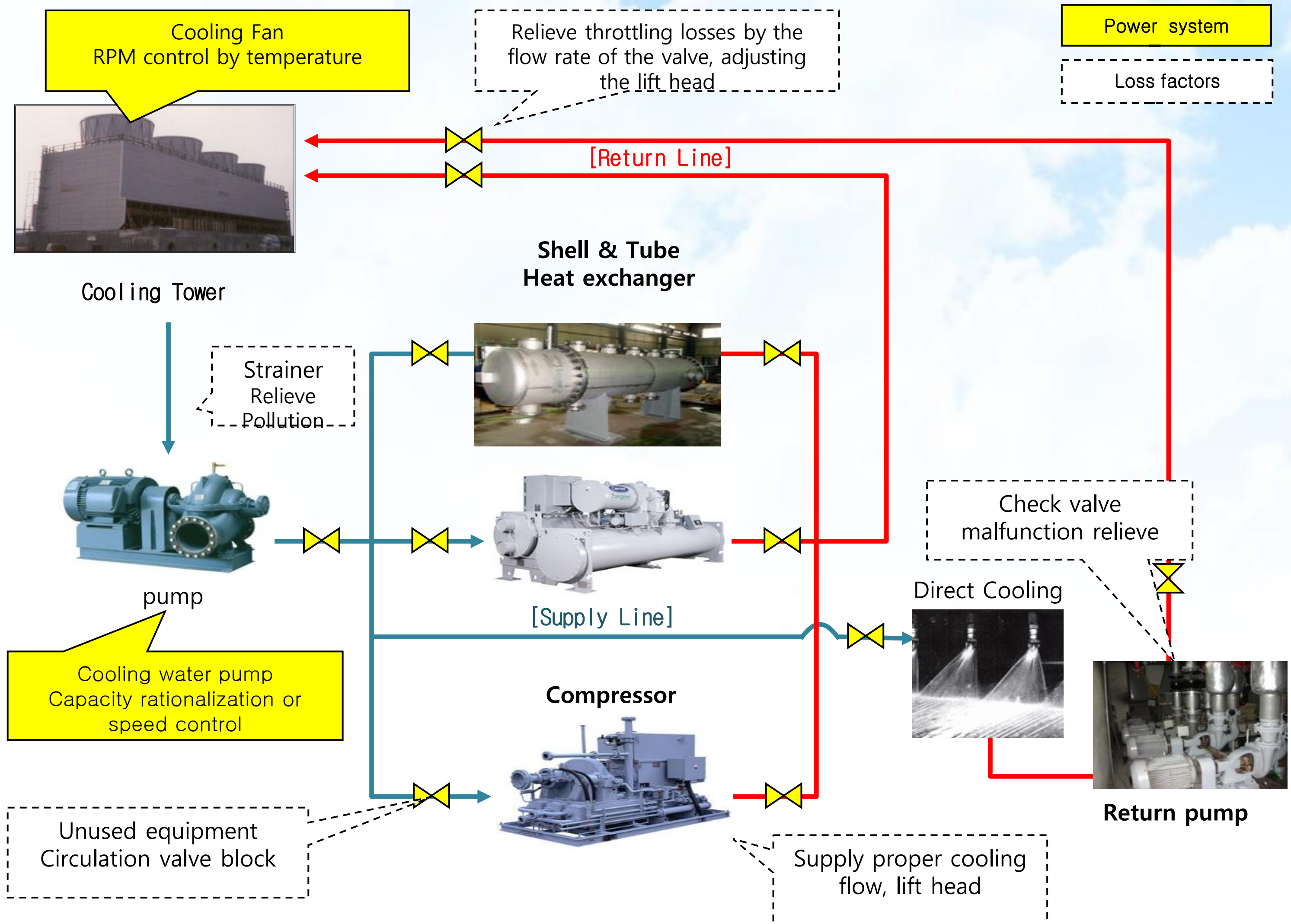
< The loss factor of the cooling water system>



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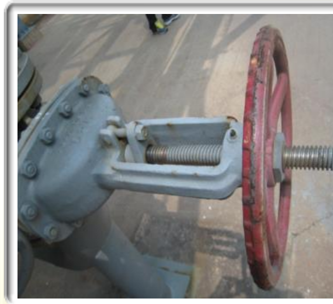
C. Procedure of pump energy audit

Check System

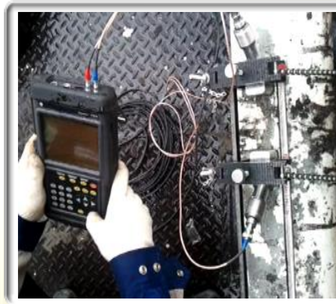
Check Nameplate

Check Valve



Check Loss factor

Measure Flow



Measure Pressure

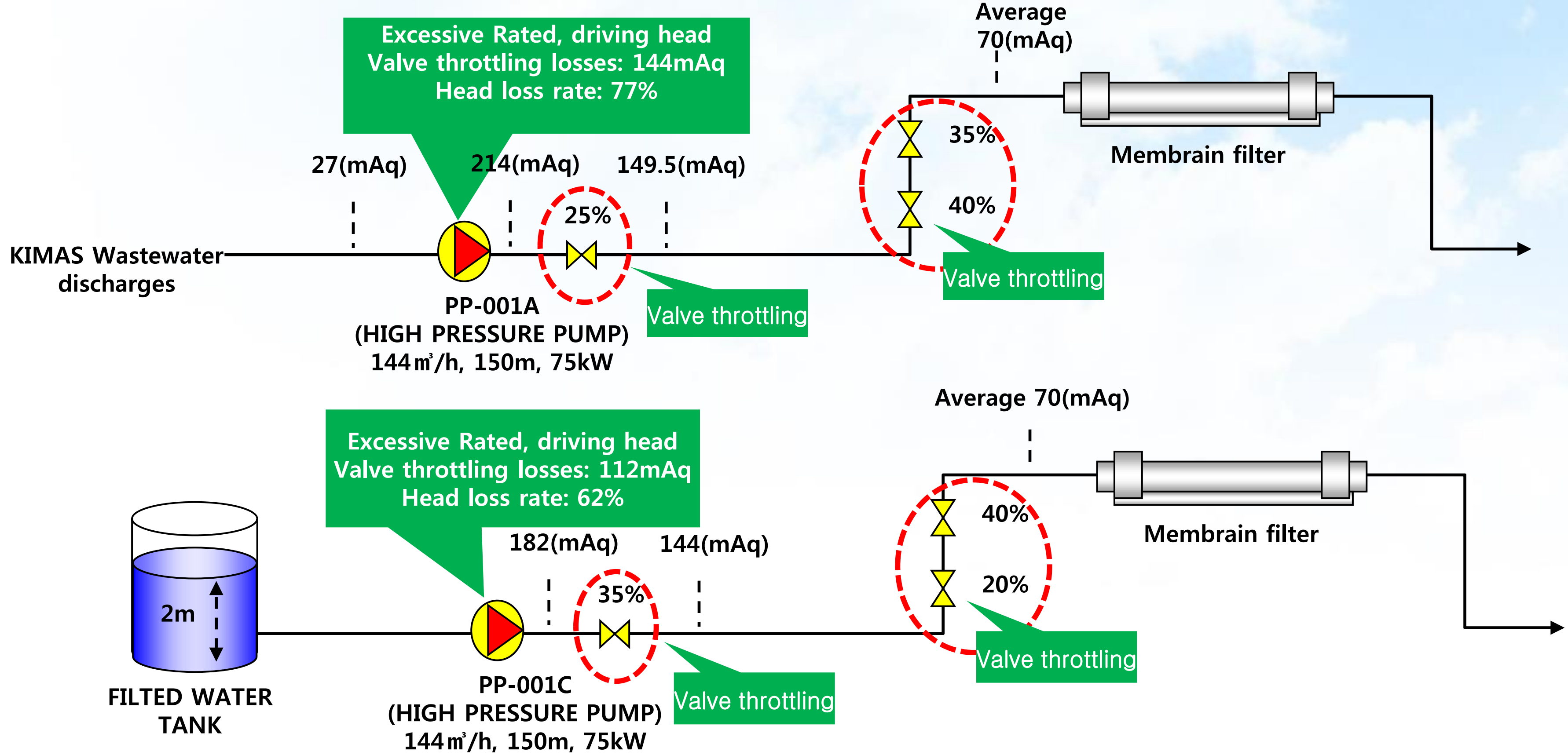
Measure Height

Measure Electric Power

Case1. Power savings and membrane protection by using inverter at RO high-pressure pump

A. Operation Status

- RO(Reverse Osmosis Membrane) System Operation Schematic



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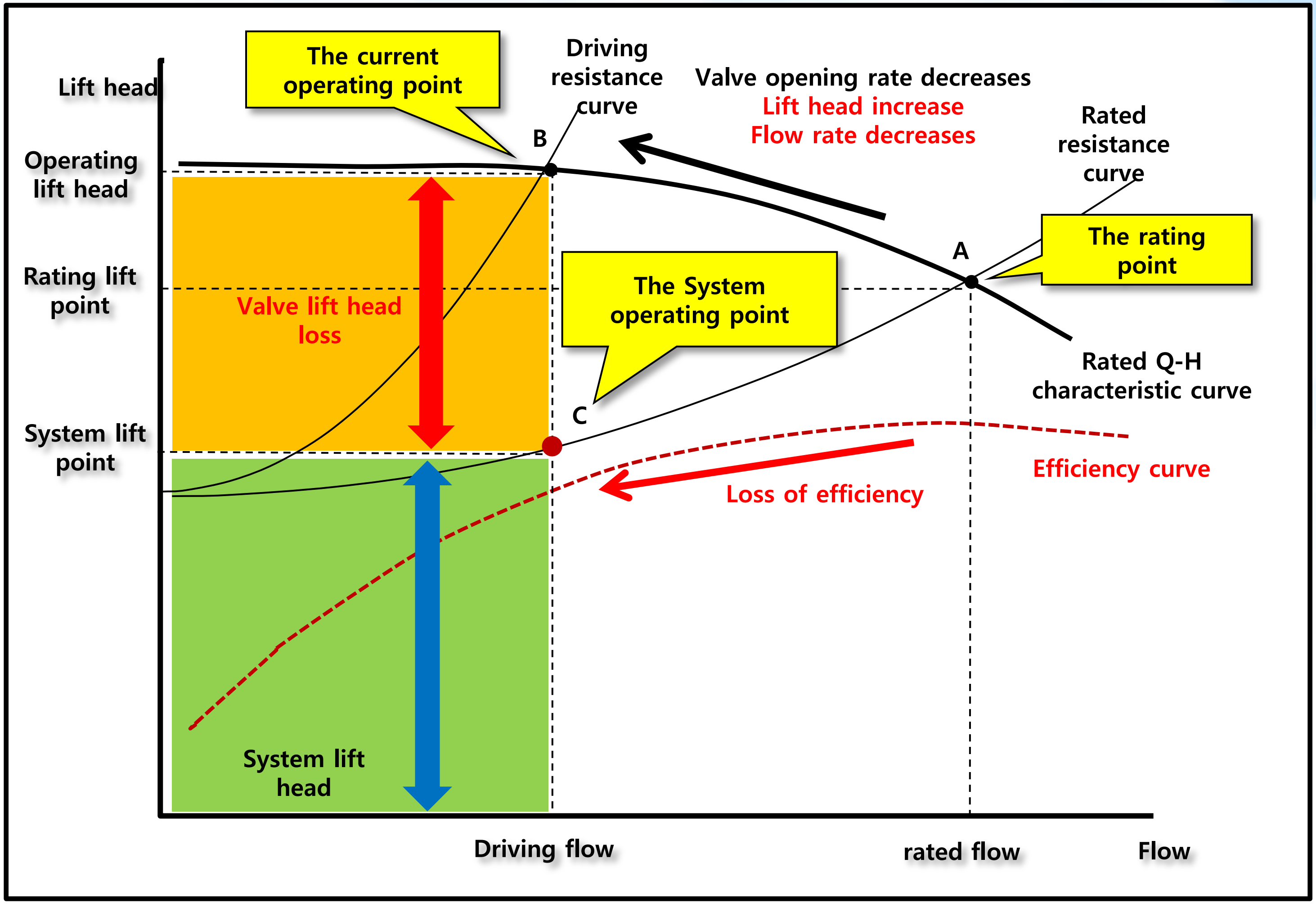
- Analyze loss factor on characteristic curve analysis



- Problem Summary

Excessive pump drive lift head compared to required pressure supply

A great loss Due to throttling valve

Shock on membrane by sudden rise of pressure when initially driving

→

Pump excessive lift head operation, Membrane damage

→

Losses of pump power consumption

B. Improvement perspective and plan

1) Improvement perspective

Relieve loss from throttling valve

Optimize the supply of the pump pressure

Review using the soft-start for cushioning shock of membrane

Decrease unnecessary pump driving head

Reduce the power consumption

Speed control by Inverter

2) Improvement plan

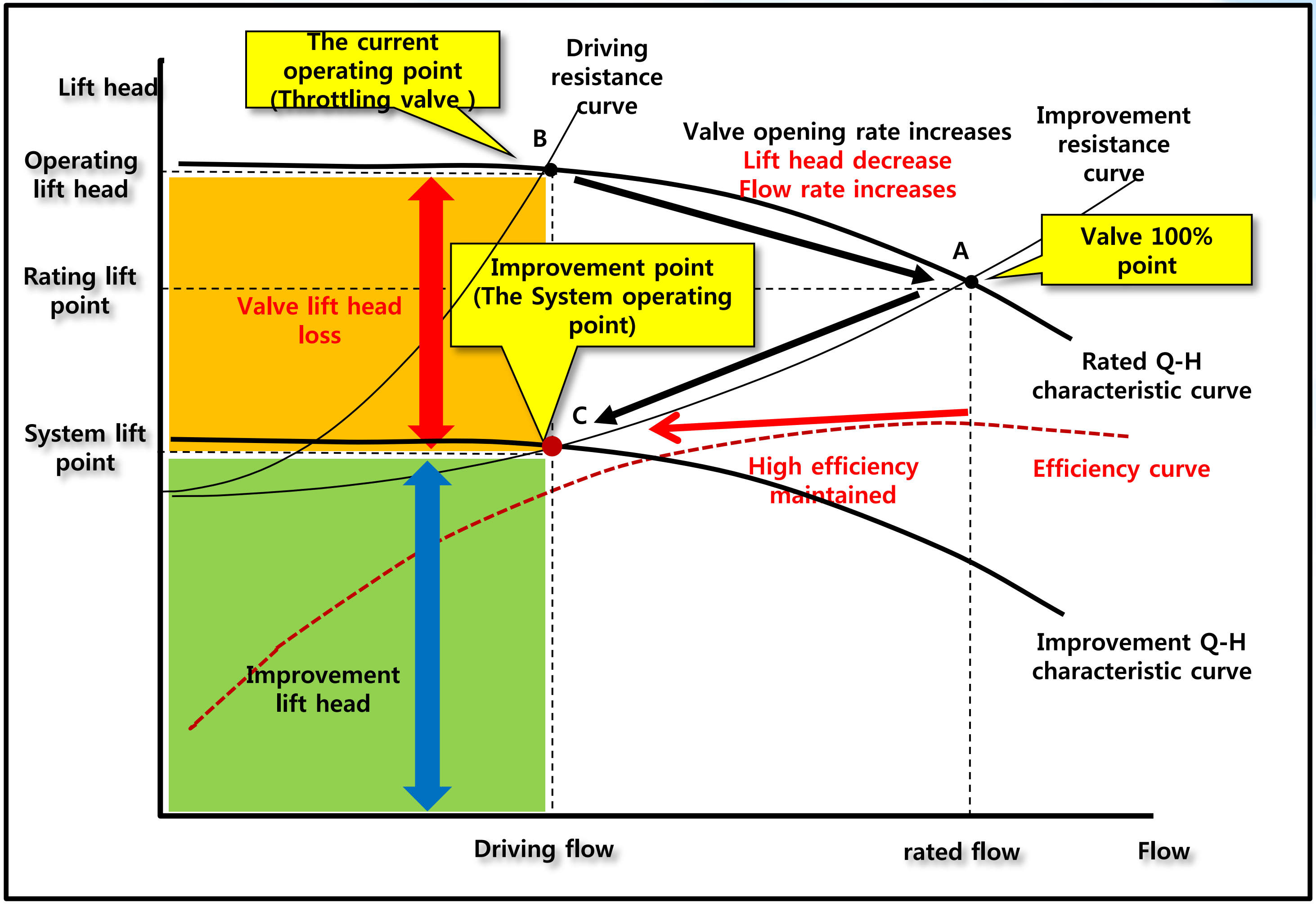
[Improvement plan 1] Speed control by Inverter + Valve opening rate 100(%) OPEN

- Use speed control by Inverter(Frequency adjustment) instead of pressure control by using valve opening rate

[Improvement plan 2] Pump Adjustments + Valve opening rate increase + Valve pressure fluctuations

- Current pump has 5 stage pump. If reduce the stage, it is possible to drive for lower pressure operating

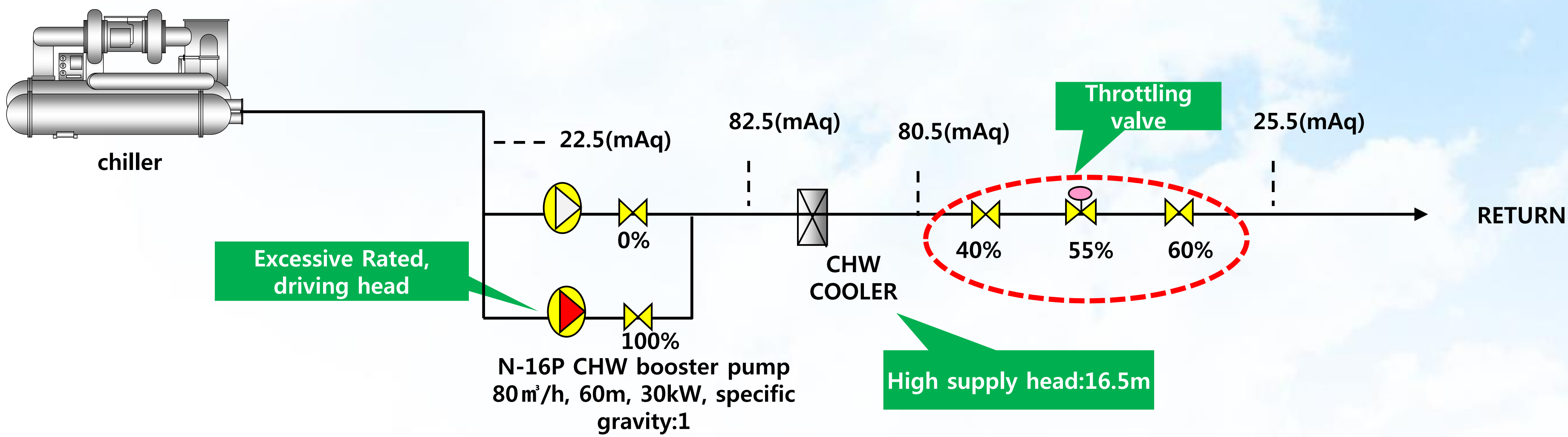
● Improvement plan 1 : Analysis improvement effect of using inverter



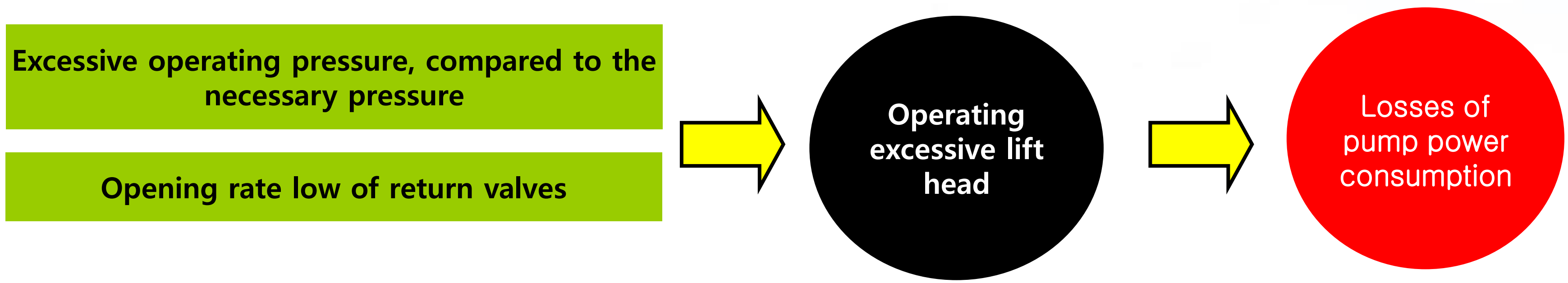
Case2. Improvement excessive CHW booster pump pressure

A. Operation Status

- Driving Schematic



- Problem Summary



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B. Improvement perspective and plan

1) Improvement perspective

Optimize operation pressure of pumps

Reduce throttling loss by maximizing valve opening rate

Use flow control system without loss of pressure

→ Decrease pump unnecessary driving head → Reduce the power consumption

Speed control by Inverter

2) Improvement plan

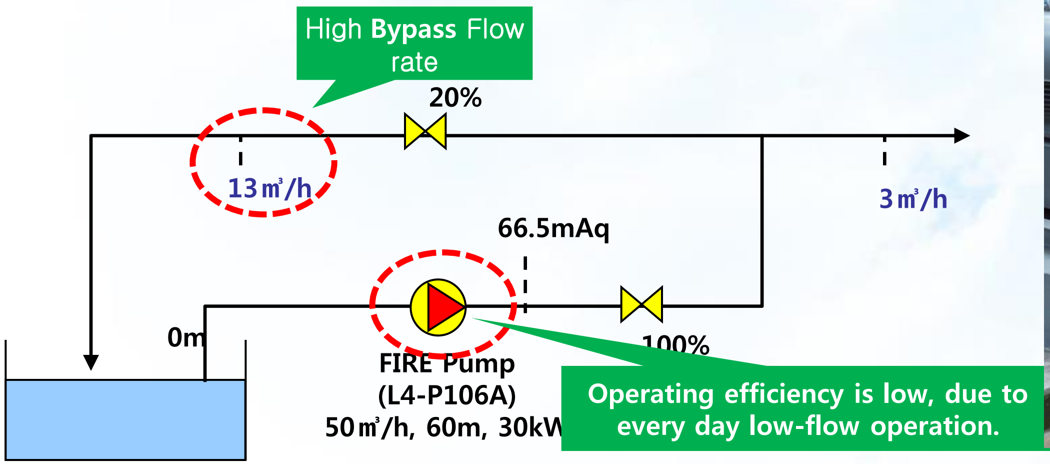
[Improvement plan] Optimization of operating pressure and increasing valve opening rate by speed control of inverter

- Supply the proper flow by opening valve 100% and control the number of revolutions by inverter
- Automatically or manually control the inverter by current flow control or signal
- By inverter, it is possible to remove the throttling losses so, can reduce the power consumption

Case3. Power saving by installing small capacity pumps for proper pressure maintained for fire water system

A. Operation Status

- Driving Schematic



[FIRE PUMP]

- Problem Summary

Operating efficiency is low, due to every day low-flow operation.

High Bypass Flow rate

→ The efficiency of operation of the pump is low, causing Bypass flow losses

→ Losses of pump power consumption

B. Improvement perspective and plan

1) Improvement perspective

Discharge valve
100% open, blocking Bypass flow

Optimization Pump operation flow and lift head

Using Control method without loss

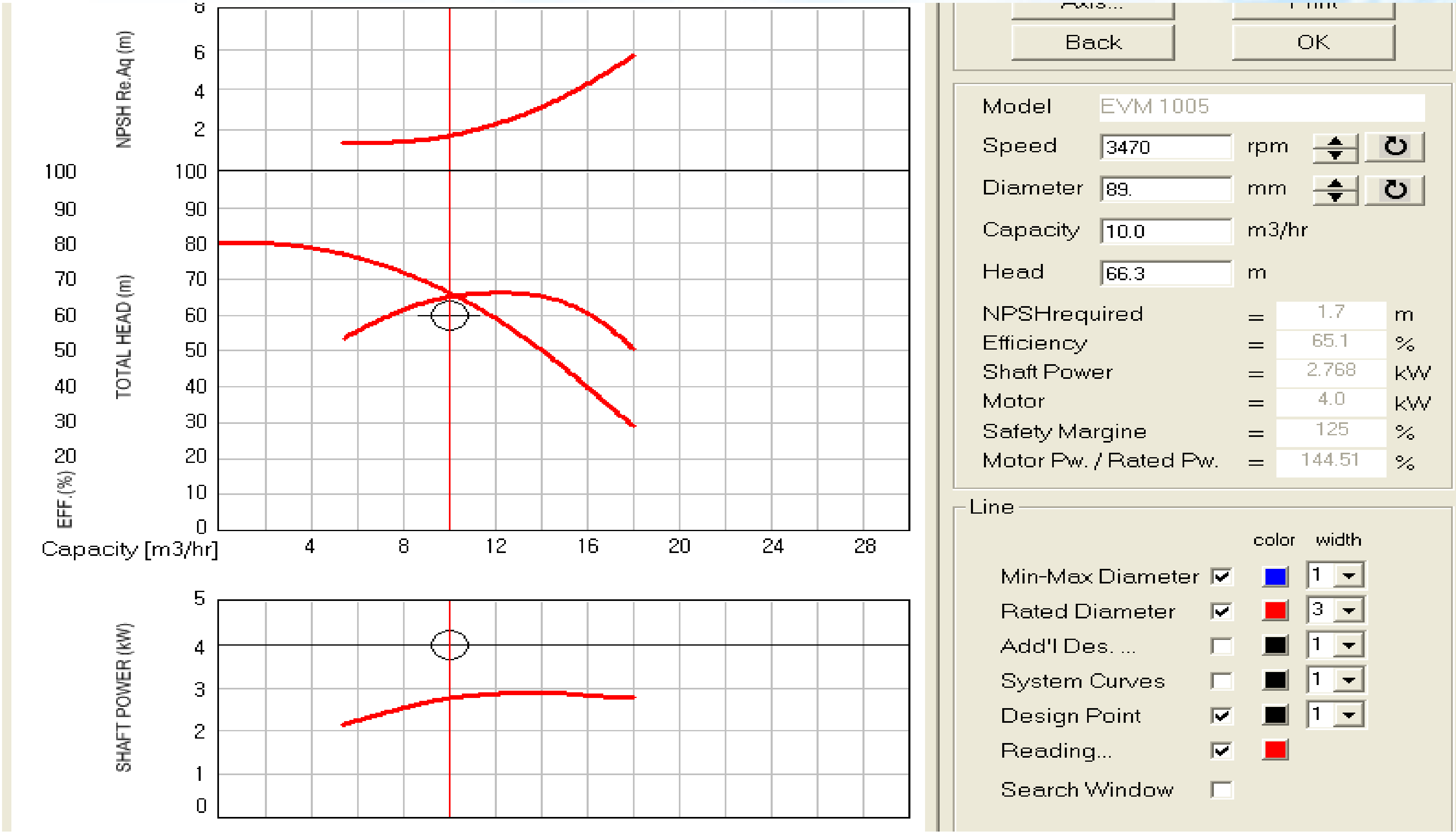
→ Decreasing unnecessary flow and lift head of pumps → Reduce the power consumption

Speed control by Inverter

2) Improvement plan

- installing small capacity pumps for proper pressure maintained for fire water system
  - Reducing the power consumption by operating rated efficiency
  - Possible partial By-pass when necessary

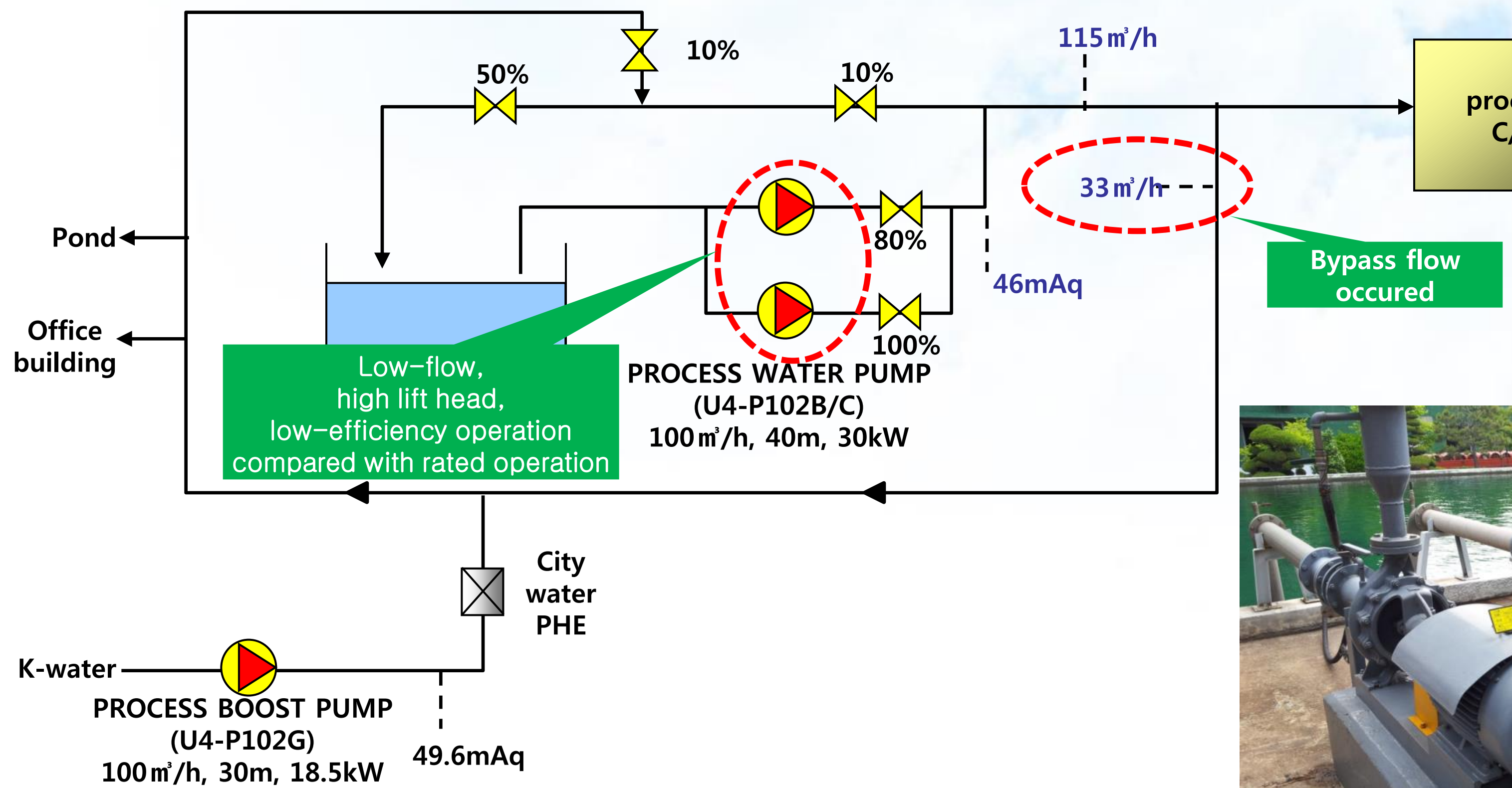
- Pump characteristic curve EVM 1005 : 10(㎥/h), 66.3(m), 3.7(kW), Rated efficiency 65.1(%)]



Case4. Integrated operation of high-efficiency pumps of process water pump

A. Operation Status

- Driving Schematic



[PROCESS WATER PUMP]

- Problem Summary

Operating efficiency is low, due to low-flow operation : 41(%)

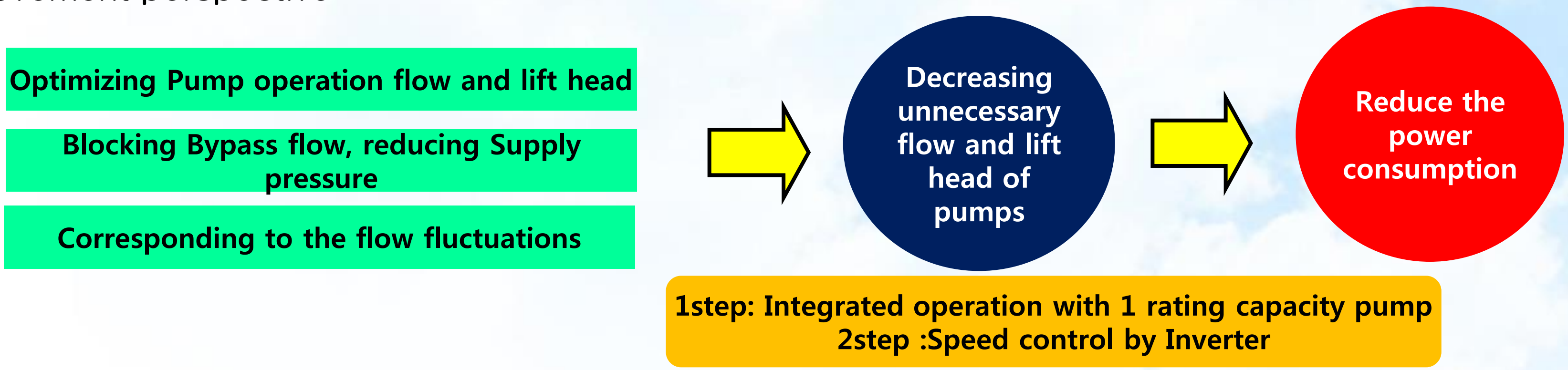
Bypass Flow : 29(%)

→ Low efficiency because of excessive lift head and low-flow unnecessary

→ Losses of pump power consumption

B. Improvement perspective and plan

1) Improvement perspective



2) Improvement plan

- Integrated operation [1 step improvement] + PIC control by Inverter [2 step improvement]

[1 step improvement]

- Integrated operation of rating capacity pump of high-efficiency operation
- Blocking Bypass flow in system

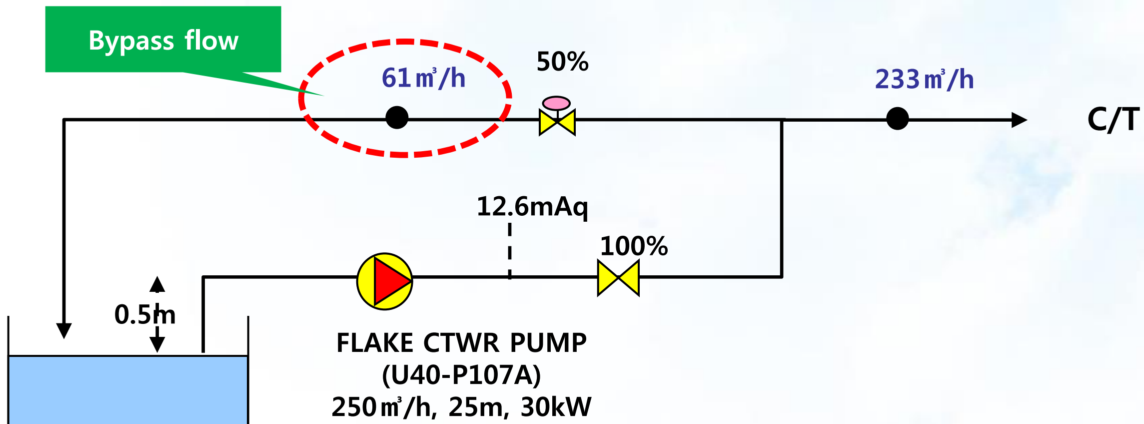
[2 step improvement]

- Enforcing PIC control to maintain the proper pressure by installing inverter

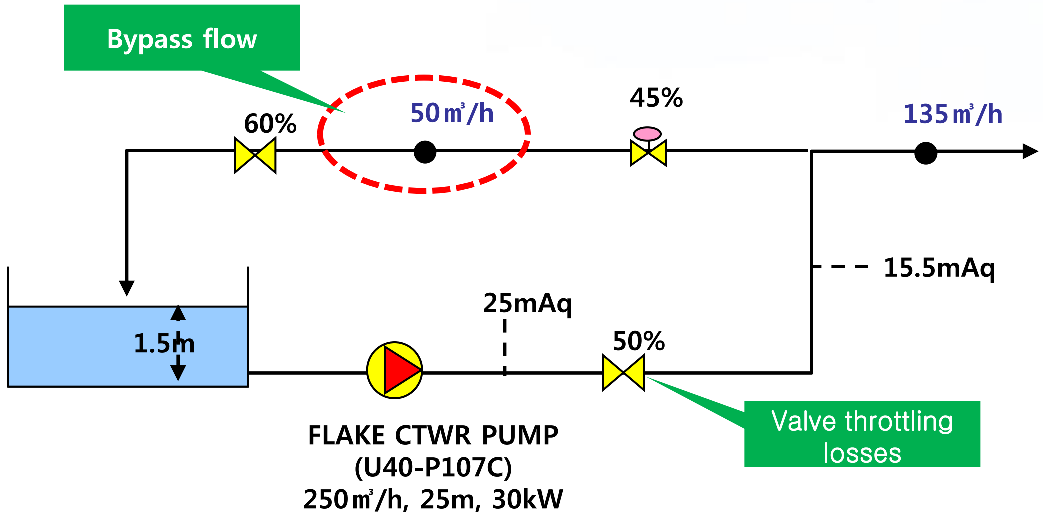
Case5. Reduce by-pass flow and pressure loss by using inverter at FLAKE CTWR PUMP

A. Operation Status and Improvement plan

- Driving Schematic



[FLAKE CTWR PUMP]



[FLAKE CTWR V/V]

- Problem Summary

Flow loss due to bypass control

lift head losses because of discharge valve throttled

Low efficiency because of excessive lift head and low-flow unnecessary

Losses of pump power consumption

- Improvement perspective

discharge valve 100% open, blocking Bypass flow

Optimizing Pump operation flow and lift head

Using Control method without loss

Decreasing unnecessary flow and lift head of pumps

Reduce the power consumption

Speed control by Inverter

- Improvement plan

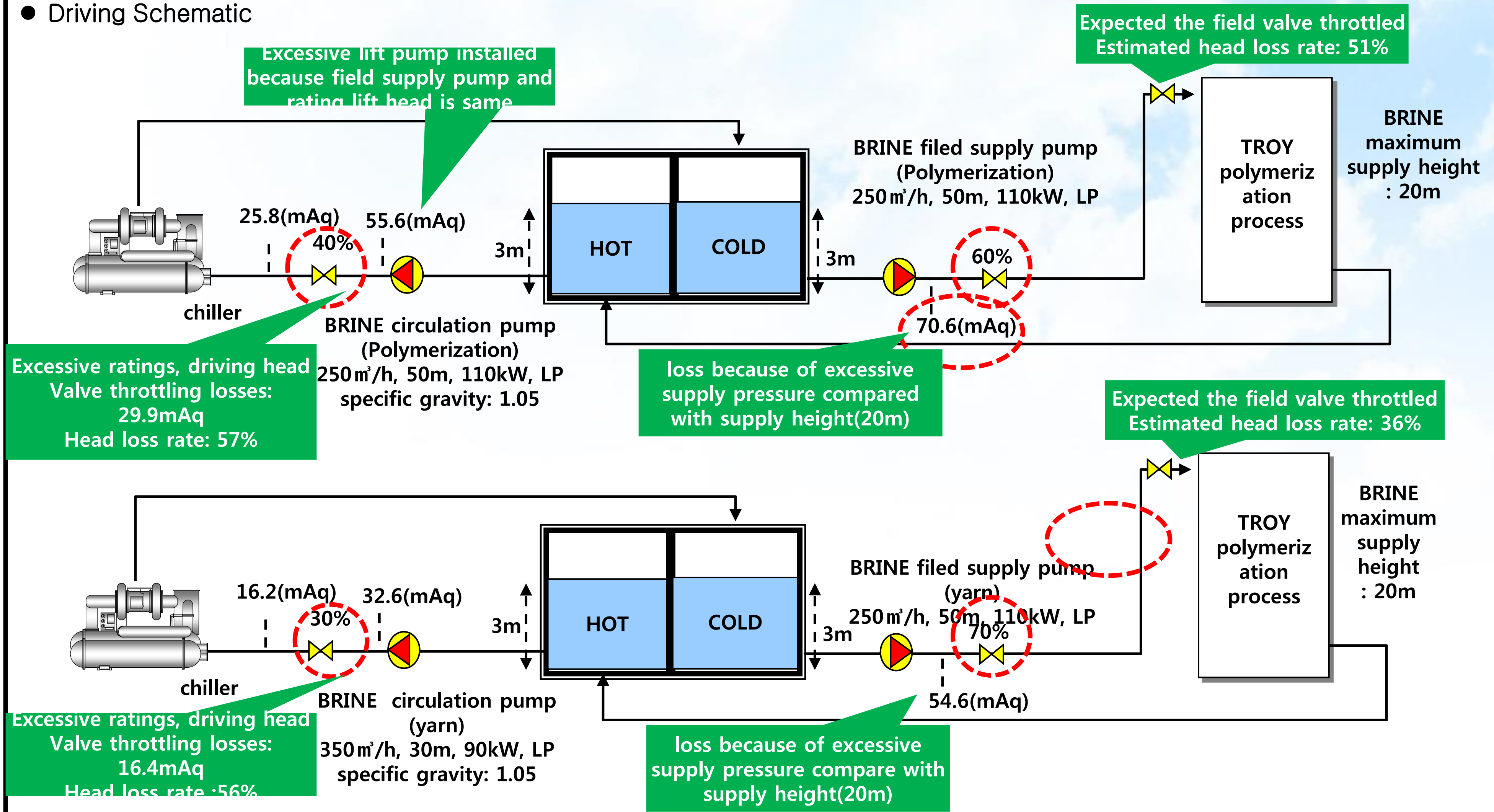
– L40-P107A Improvement plan) discharge valve LIC control + Bypass flow blocking

– L40-P107C Improvement plan) Speed control by Inverter + Bypass flow blocking+ Valve 100% Open

Case6. Improving valve loss in brine pump system and unifying system

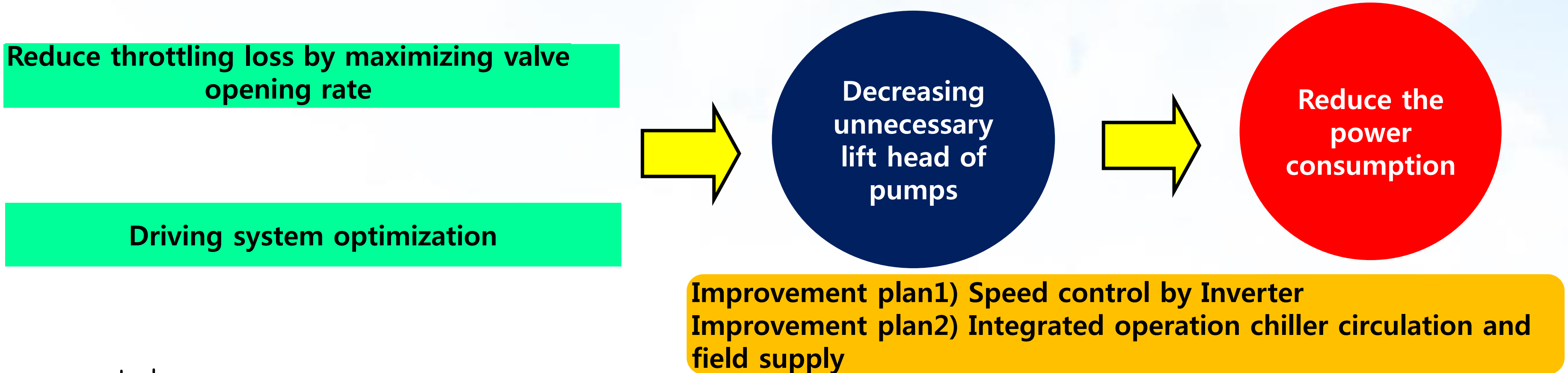
A. Operation Status and Improvement plan

● Driving Schematic



- Problem Summary

- Improvement perspective

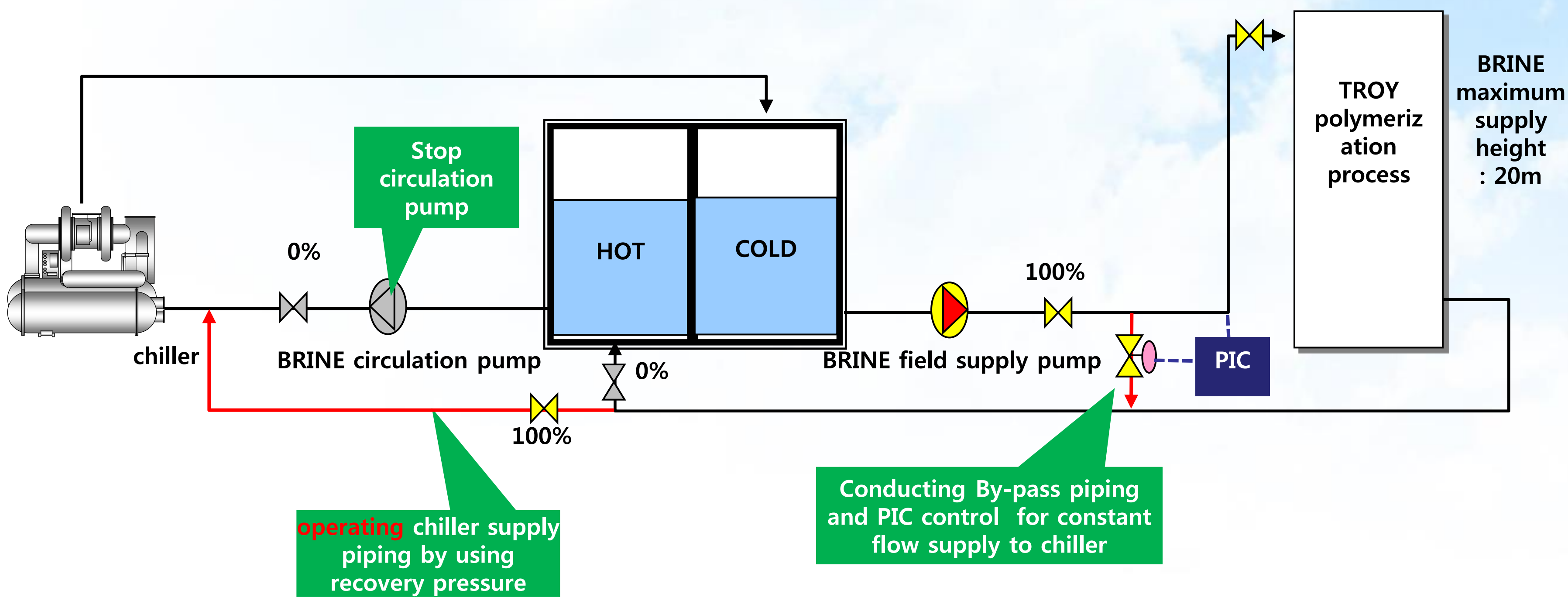


- Improvement plan

– Improvement plan1) optimization operating pressure by Speed control by Inverter + Reduce throttling loss by maximizing valve opening rate

– Improvement plan2) Integrated operation chiller circulation and field supply

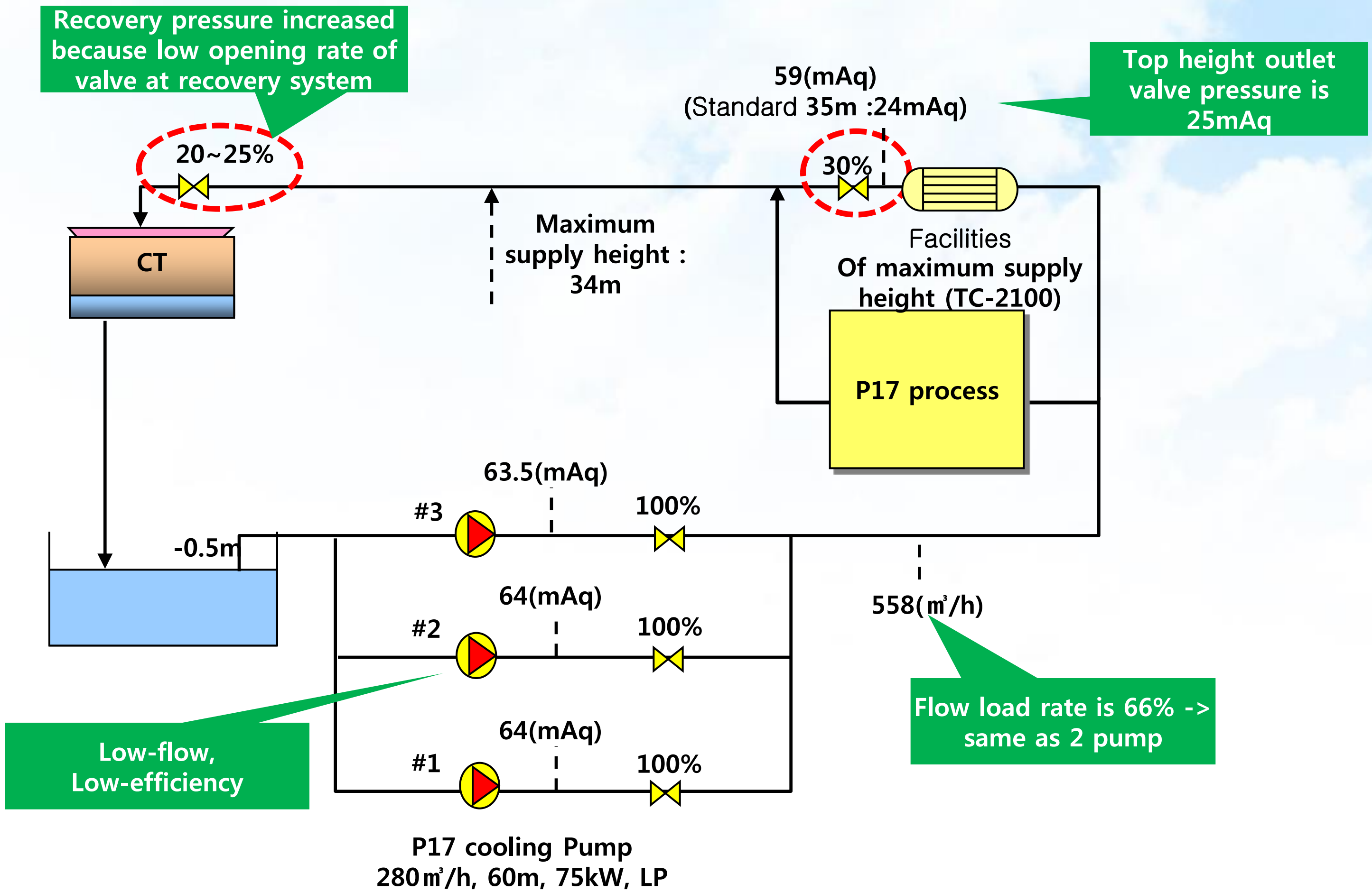
● Driving Schematic (Improvement plan 2)



Case7. Reducing pressure loss at Cooling water system

A. Operation Status

- Driving Schematic



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- Problem Summary

Additional recovery pressure occurs because of excessive head

Pressure loss because of throttling valve

Low Operating efficiency is expected, due to low-flow operation

→

Low efficiency because of excessive lift head unnecessary

→

Losses of pump power consumption

B. Improvement perspective and plan

1) Improvement perspective

Reduce throttling loss by maximizing valve opening rate

Optimizing Pump operation lift head

Decreasing unnecessary lift head of pumps

Reduce the power consumption

plan1) Two high-efficiency pump operation
plan2) Existing 3 pumps -> 2 pump
plan3) Speed control by Inverter

2) Improvement plan

[Improvement plan1]) Two high–efficiency pump operation+ maximizing valve opening rate

- After improvement, a highly efficient operation is possible by reducing lift head (need to check replacement of small size impeller)

[Improvement plan2] stop 1 pump after 2 pump operation+ maximizing valve opening rate

- After improvement Operation Unit of the division flow increases. However, Highly efficient operation is possible because of rating operation

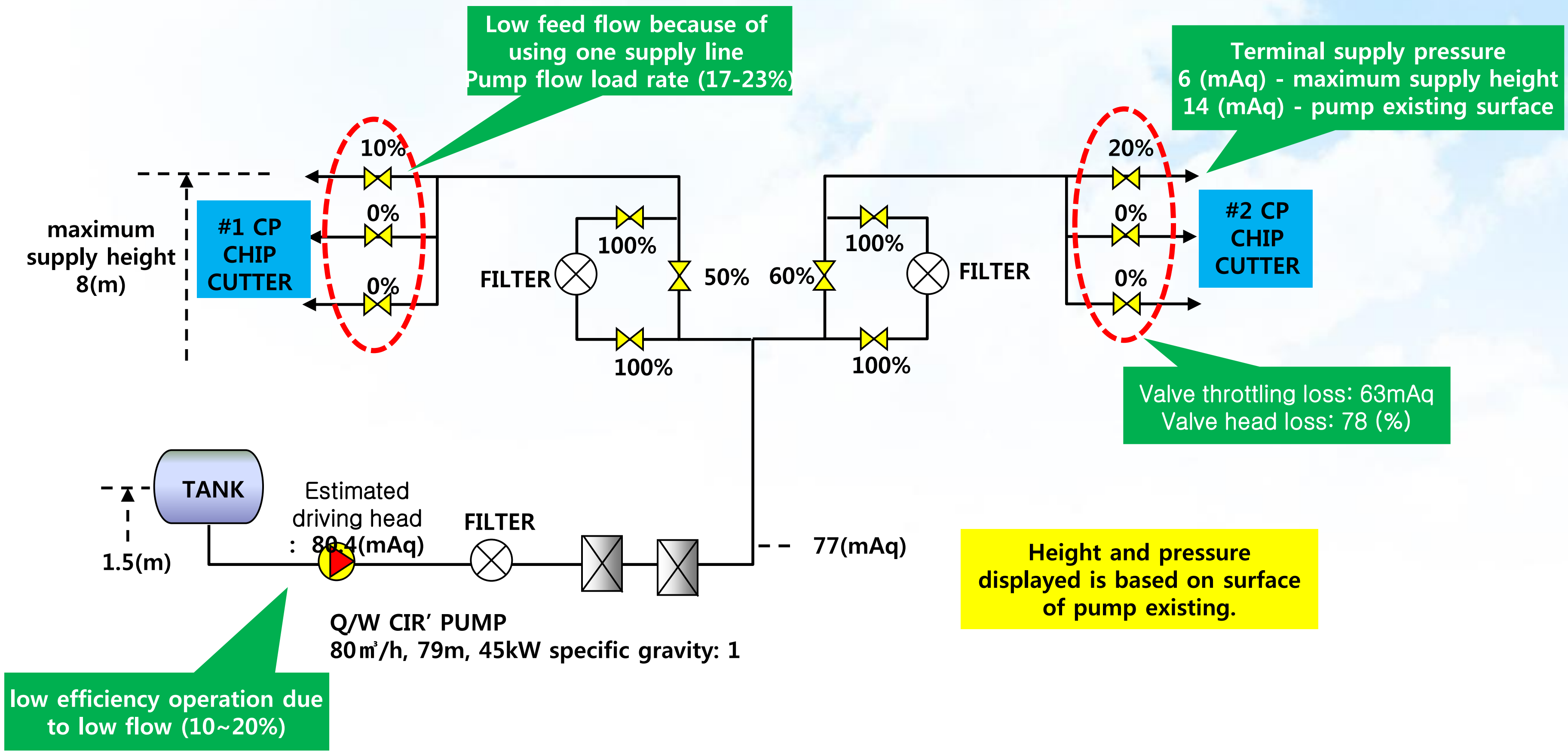
[Improvement plan3] Speed control by Inverter + maximizing valve opening rate

- Conducting speed control by install inverter each unit for proper supply pressure

Case8. Improvement quench water circulation pump operation efficiency

A. Operation Status

- Driving Schematic



- Problem Summary

excessive lift head operation

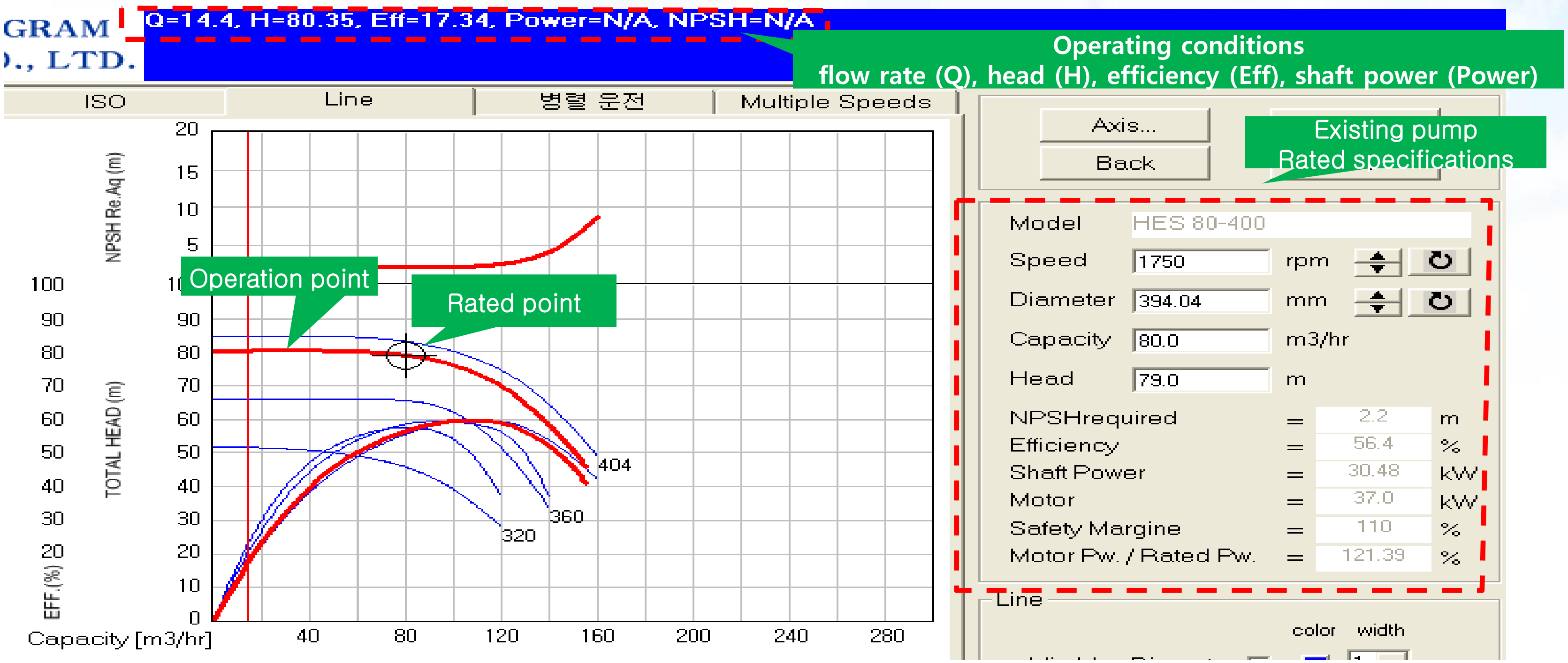
Pressure loss because of throttling valve

low efficiency operation due to low flow

Low efficiency because of excessive lift head unnecessary

Losses of pump power consumption

- Characteristic curve analysis



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B. Improvement perspective and plan

1) Improvement perspective

Minimize loss due to throttling valve

Optimization Pump operation lift head

promoting high-efficiency operation,

→ **Decreasing unnecessary lift head of pumps** → **Reduce the power consumption**

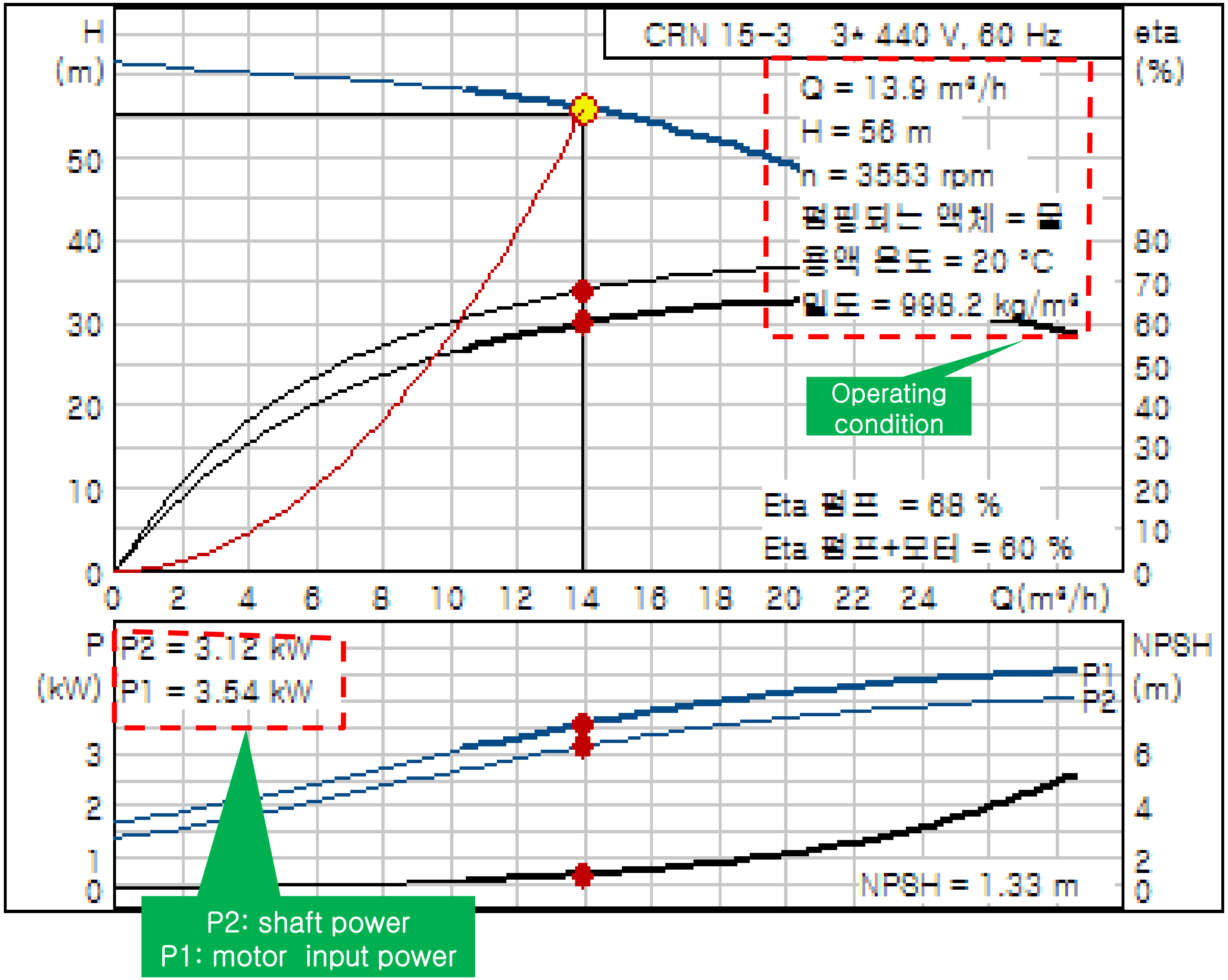
Plan 1) Replacement pump
Plan 2) Install inverter

2) Improvement plan

[Improvement plan 1] replacing optimal size pump + maximizing valve opening rate at the end of valve

[Improvement plan 2] inverter control+ maximizing valve opening rate at the end of valve

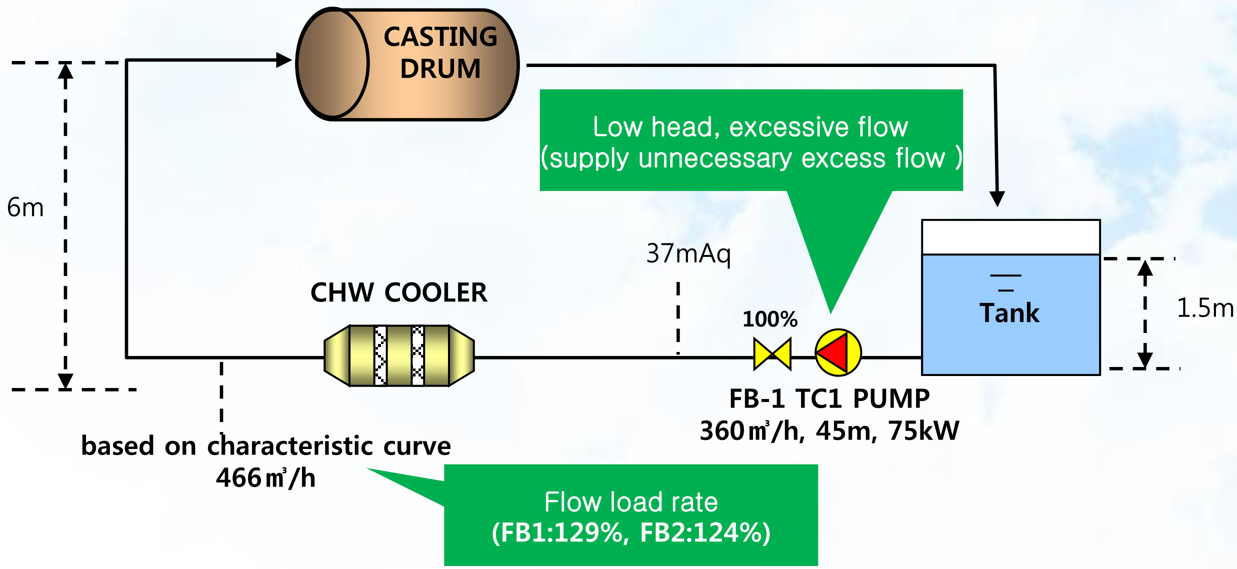
● Characteristic curve analysis(Improvement plan 1)



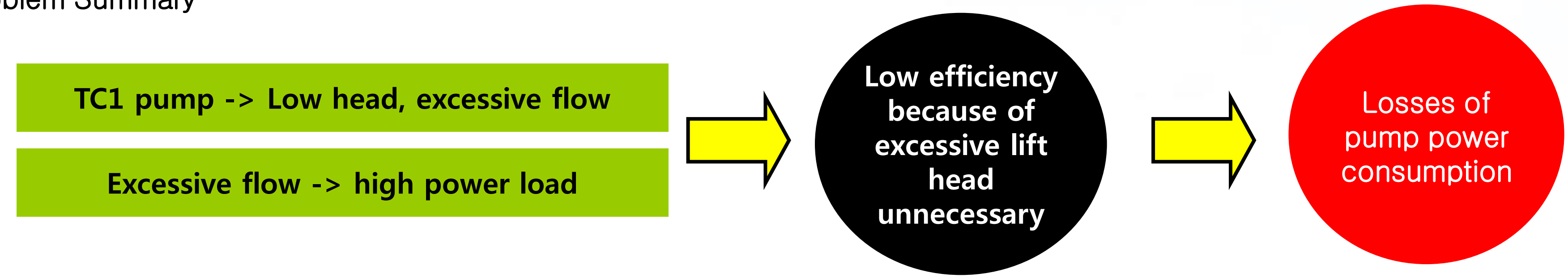
Case9. Rated flow driving by improving excessive flow pump

A. Operation Status

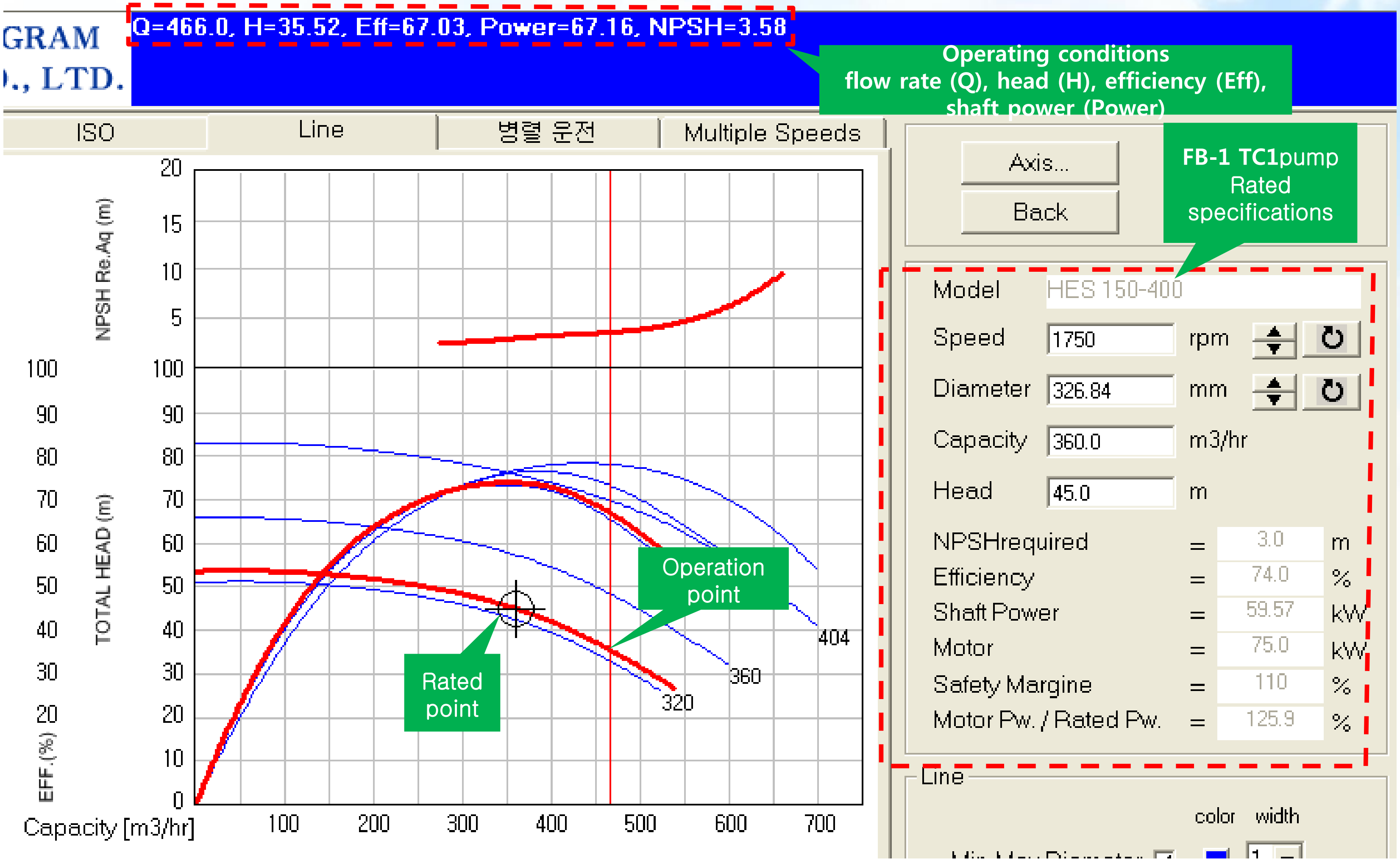
- Driving Schematic



- Problem Summary



● Characteristic curve analysis current pump



[FB-1 TC1 pump characteristic curve]

B. Improvement perspective and plan

1) Improvement perspective

Driving with a pump rated flow value

Check to decrease additional driving flow

Decreasing unnecessary flow of pumps

Install inverter

Reduce the power consumption

2) Improvement plan

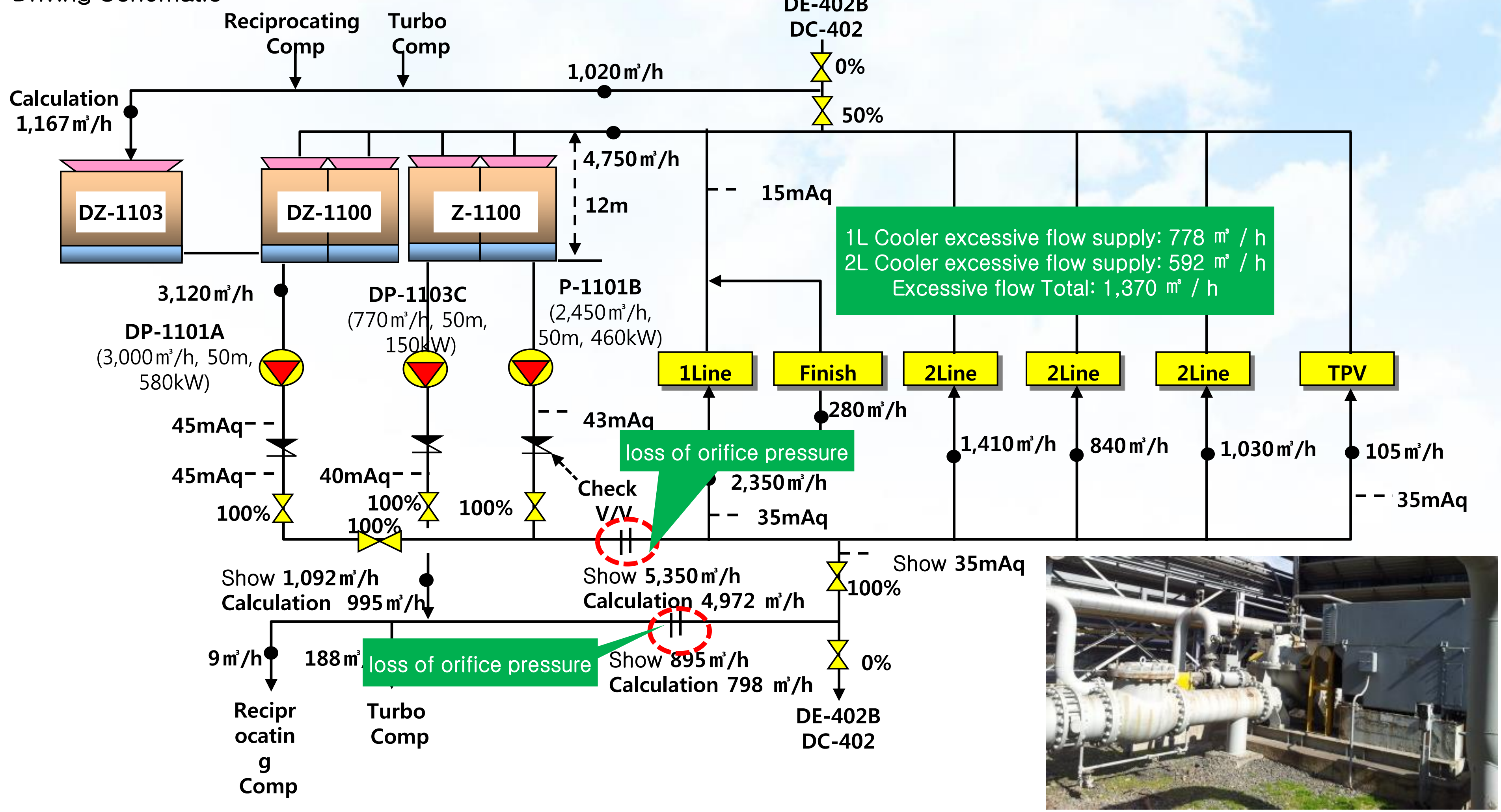
[Improvement plan] Driving rated flow by inverter control

- By inverter control, keep the rated flow

Case10. Improve loss of process cooling water system

A. Operation Status

- Driving Schematic



- Problem Summary

Pressure loss due to the orifice: 5~10(mAq)

Excessive flow supply some of Coolers: 1,370(㎥/h)

Difficulties of control of precision flow

→ **Increasing of operating flow rate and lift head of COW pump**

→ **Losses of pump power consumption**

- Oriffice picture

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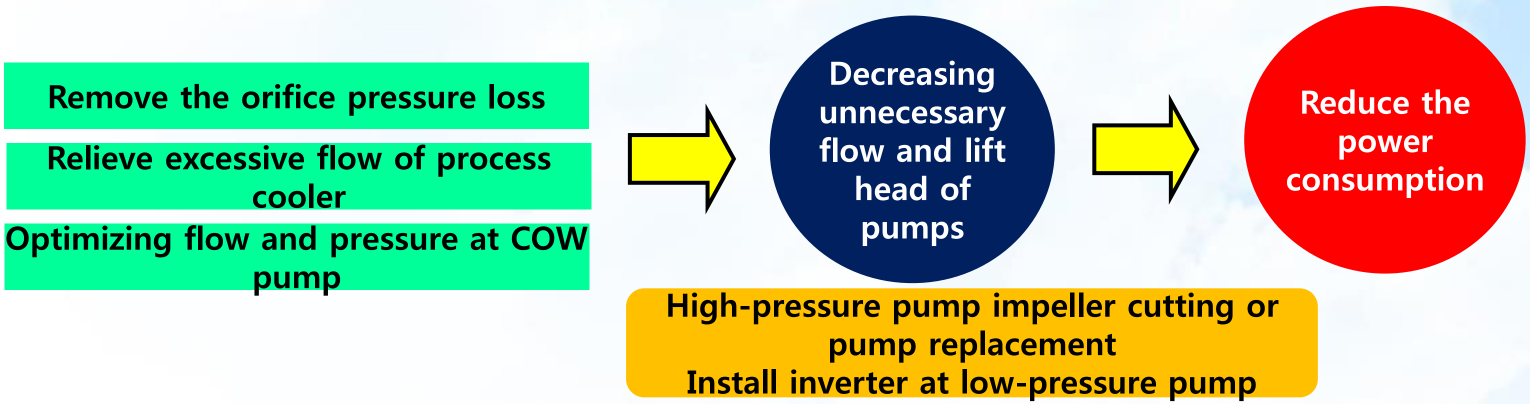
B. Improvement perspective and plan

1) Improvement perspective



2) Improvement plan

- Improvement plan1) Remove the orifice pressure loss + Relieve excessive flow of process Cooler + High pressure pump impeller cutting + Install inverter at low-pressure pump

- Improvement plan2) Remove the orifice pressure loss + Relieve excessive flow of process Cooler + Replaced high-efficiency pump + Install inverter at low-pressure pump

2. FAN UTILITY

2. FAN utility

A. FAN overview

◆ What is FAN(BLOWER) ?

A machine that converts energy from mechanical energy to pressure and velocity energy.

◆ Name by pressure

Air blower		Compressor
Fan	Blower	Compressor
1,000mmAq under (0.1kg/cm² under)	1,000~10,000 mmAq under (0.1~1.0kg/cm² under)	10,000mmAq more than (1kg/cm² more than)

◆ FAN(BLOWER) power equation

$$\text{FAN POWER}(kW) = \frac{Q(m^3/min) \times H(mmAq)}{6120 \times \eta_{(Fan)} \times \eta_{(MOTOR)}}$$

N(revolutions per minute(RPM)) ∝Flow(Q) , N(RPM) ∝Lift Head²(H) , P(Power) ∝ Flow(Q) x Lift Head(H)

☞ **P(Power) ∝RPM³(N)**

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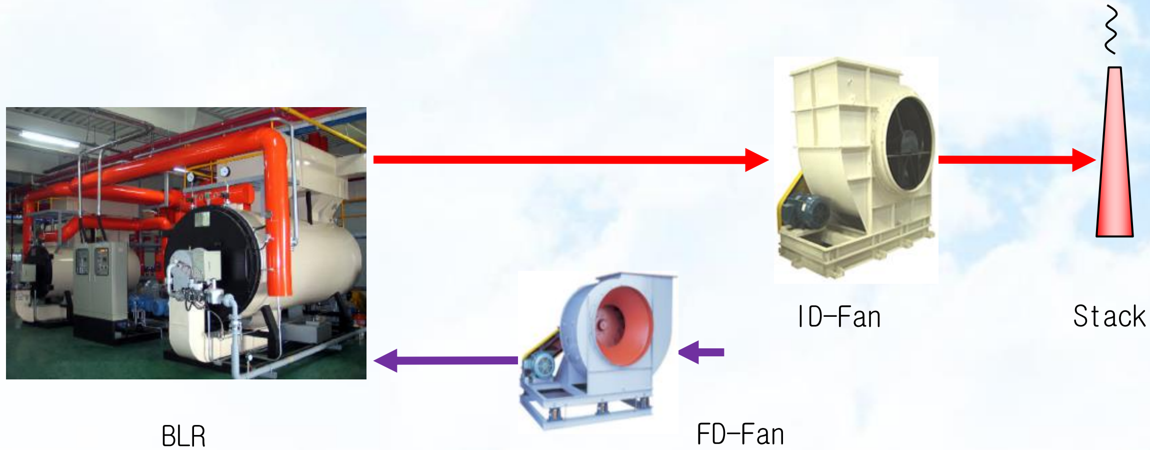
◆ FAN Uses

[BLR system]



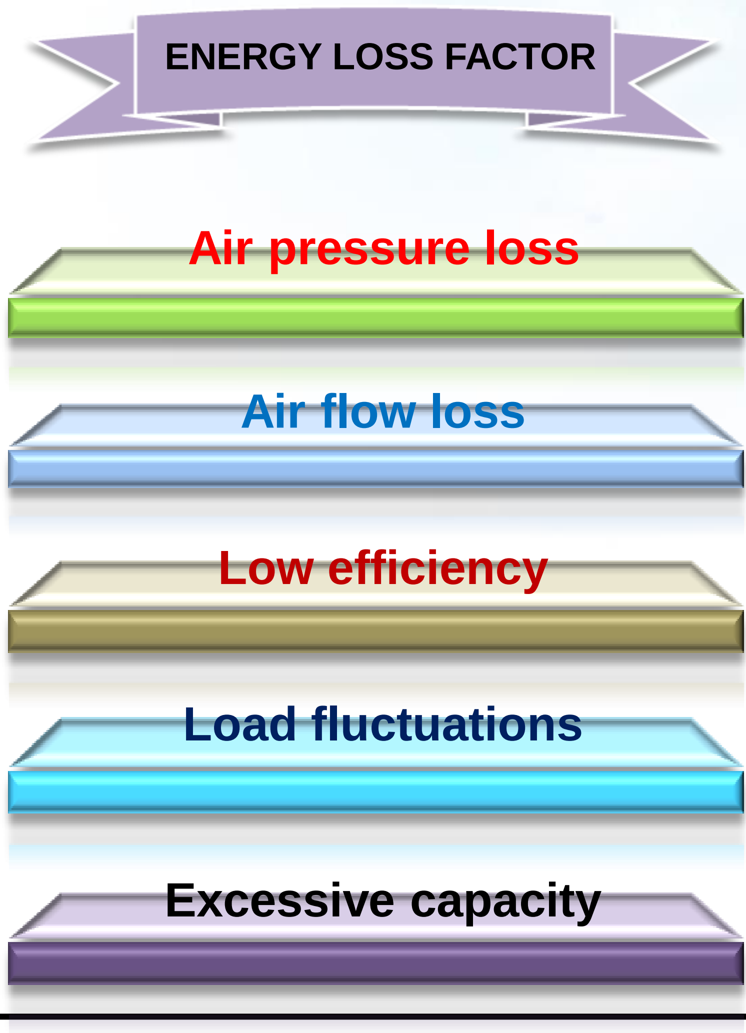
[Dusting]

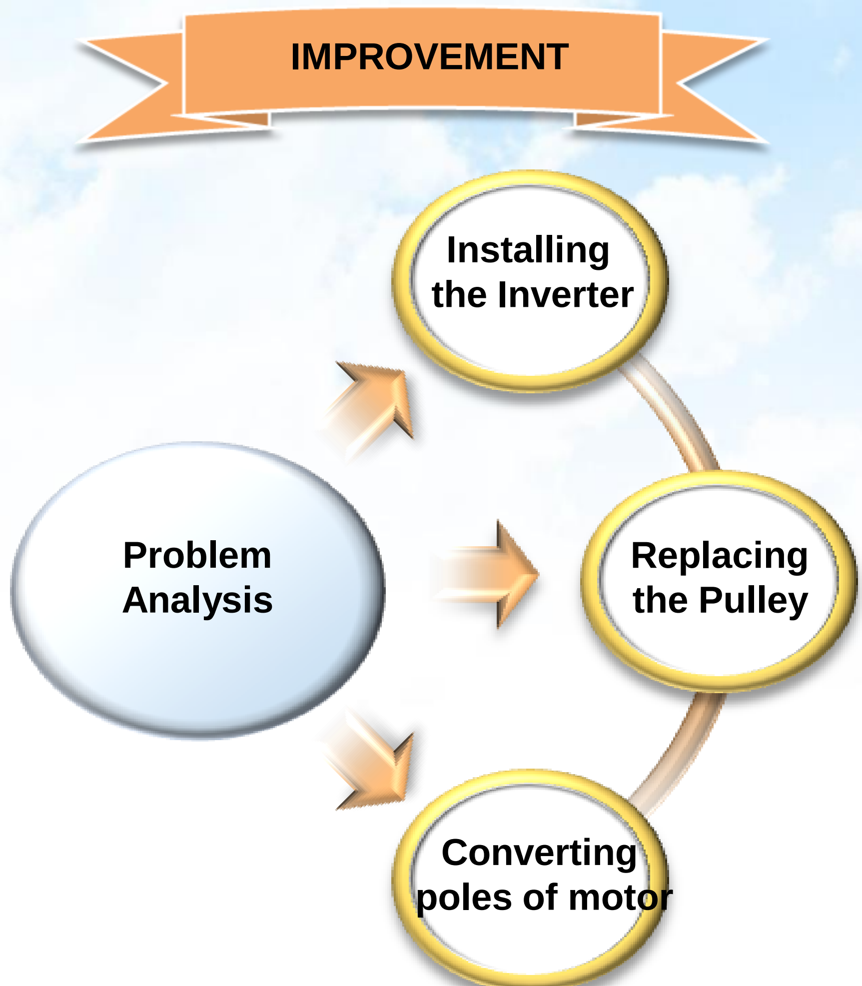
[Air handling]

[Cooling]

[Ventilating

B. FAN Energy loss factor and Improvement plan





C. Procedure of fan energy audit

Check System

Check Nameplate

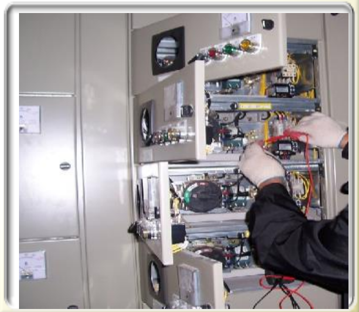
Check Damper

Determine loss factor

Measure Air Flow

Measure Air Pressure

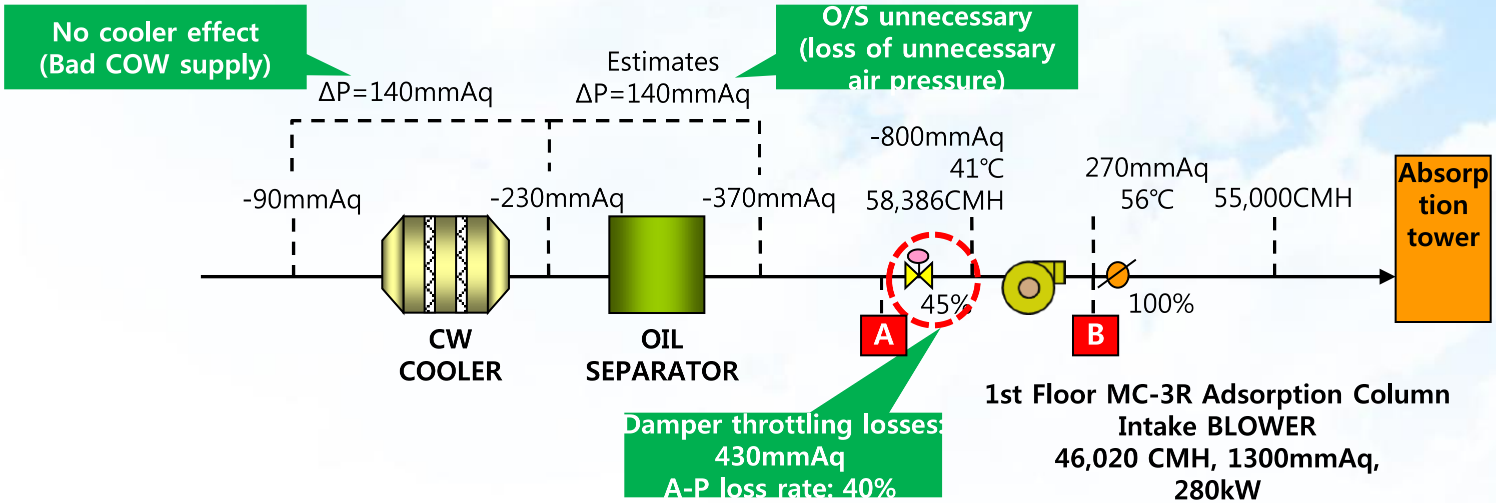
Measure Electric Power



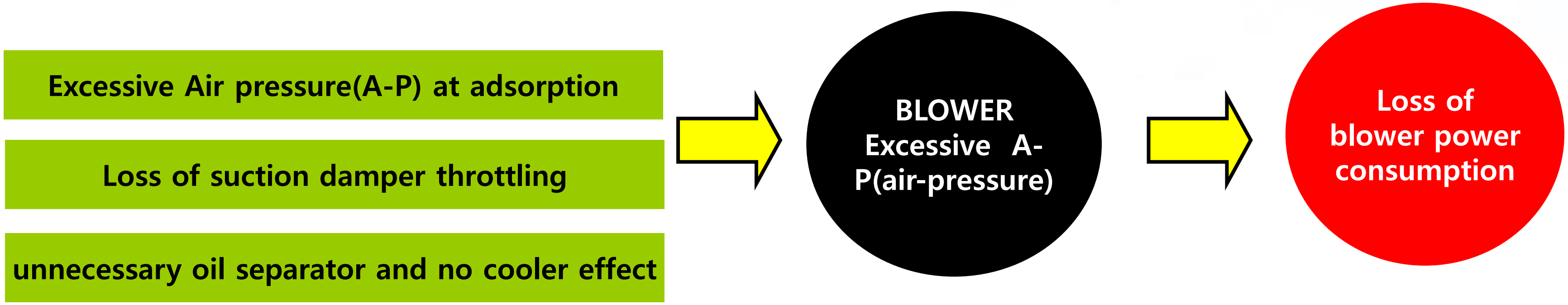
Case1. Reducing loss of Air-pressure(A-P) and optimizing capacity at adsorption column intake blower system

A. Operation Status

- Driving Schematic



- Problem Summary



B. Improvement perspective and plan

1) Improvement perspective

Optimizing blower pressure

Maximizing the damper opening rate

Elimination loss of unnecessary A-P

→ **Reducing unnecessary driving head of blower** → **Reducing blower power consumption**

replacement proper capacity blower

2) Improvement plan

[Improvement plan 1] Remove unnecessary A–P loss and replace optimization capacity blower at oil separator

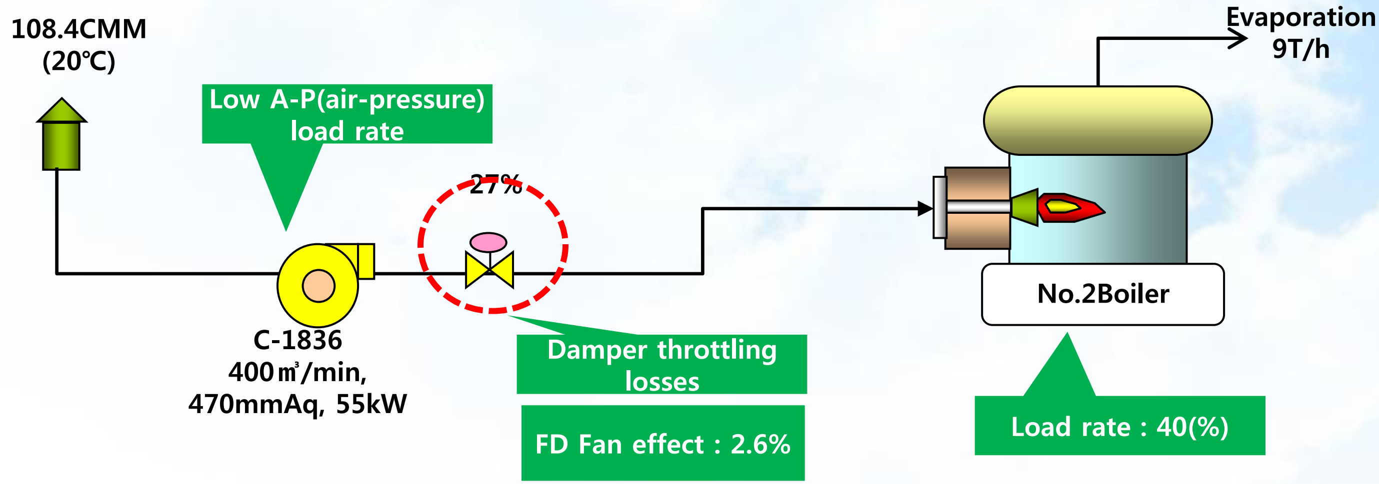
[Improvement plan 2] Use oil separator and replace optimization capacity blower

[Improvement plan 3] Remove unnecessary Oil separator, cooler A–P loss and replace optimization capacity blower

Case2. Improvement damper loss by installing inverter at BLR FD fan

A. Operation Status

- Driving Schematic



- Problem Summary

Low A-P(air-pressure) load rate at FD Fan

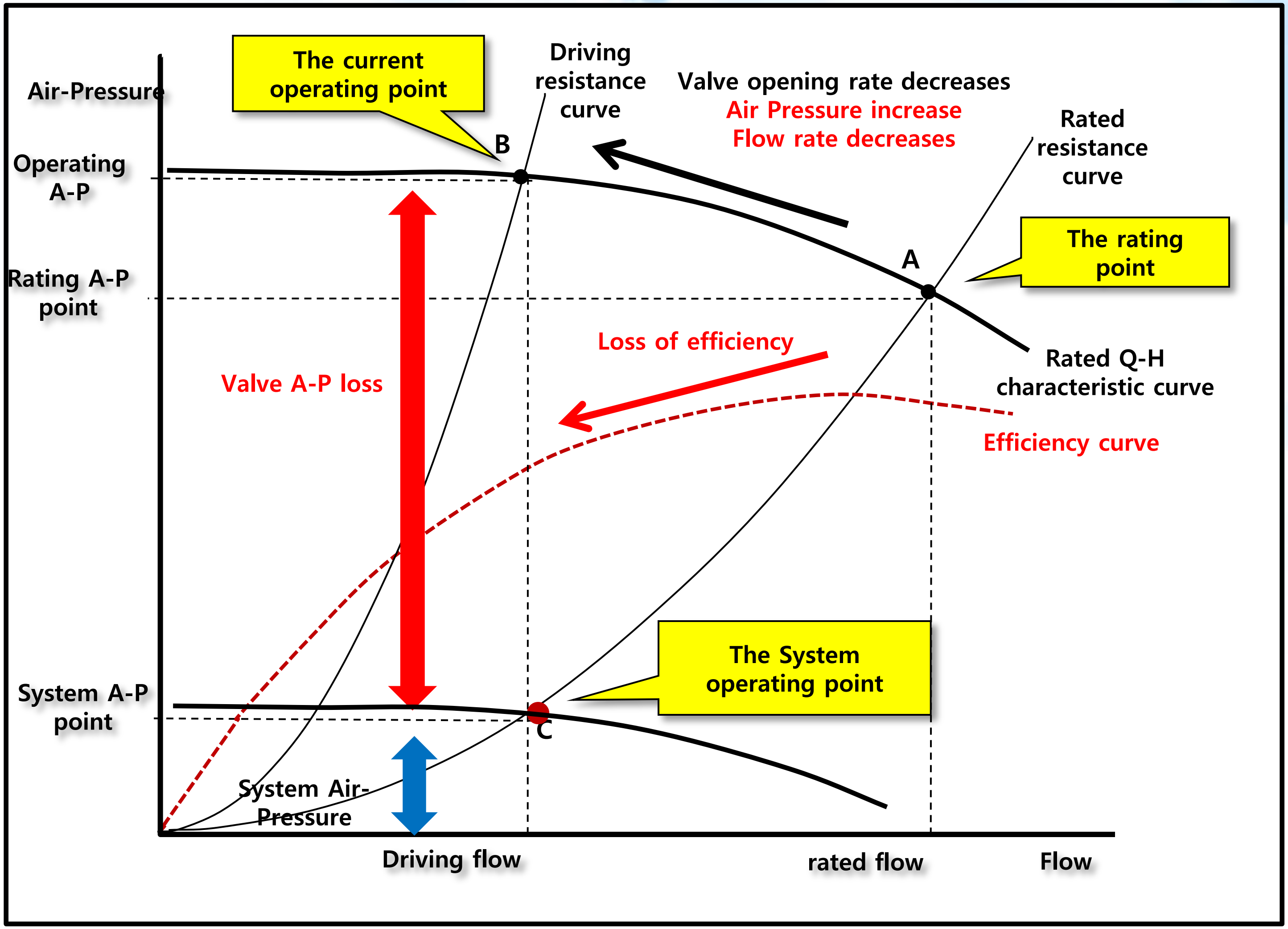
Loss of A-P of low damper opening rate(27%)

Low FD Fan effect(2.6%)

→ Loss of damper A-P and low effect of system

→ Loss of blower power consumption

- Analysis loss factor on characteristic curve



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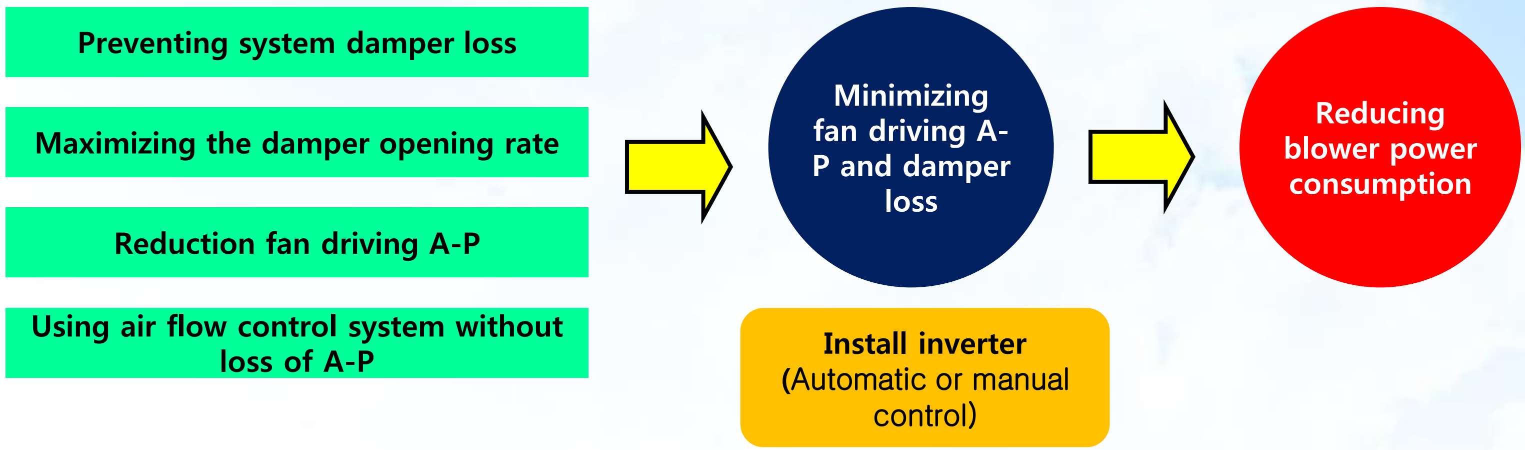
B. Improvement perspective and plan

1) Improvement perspective



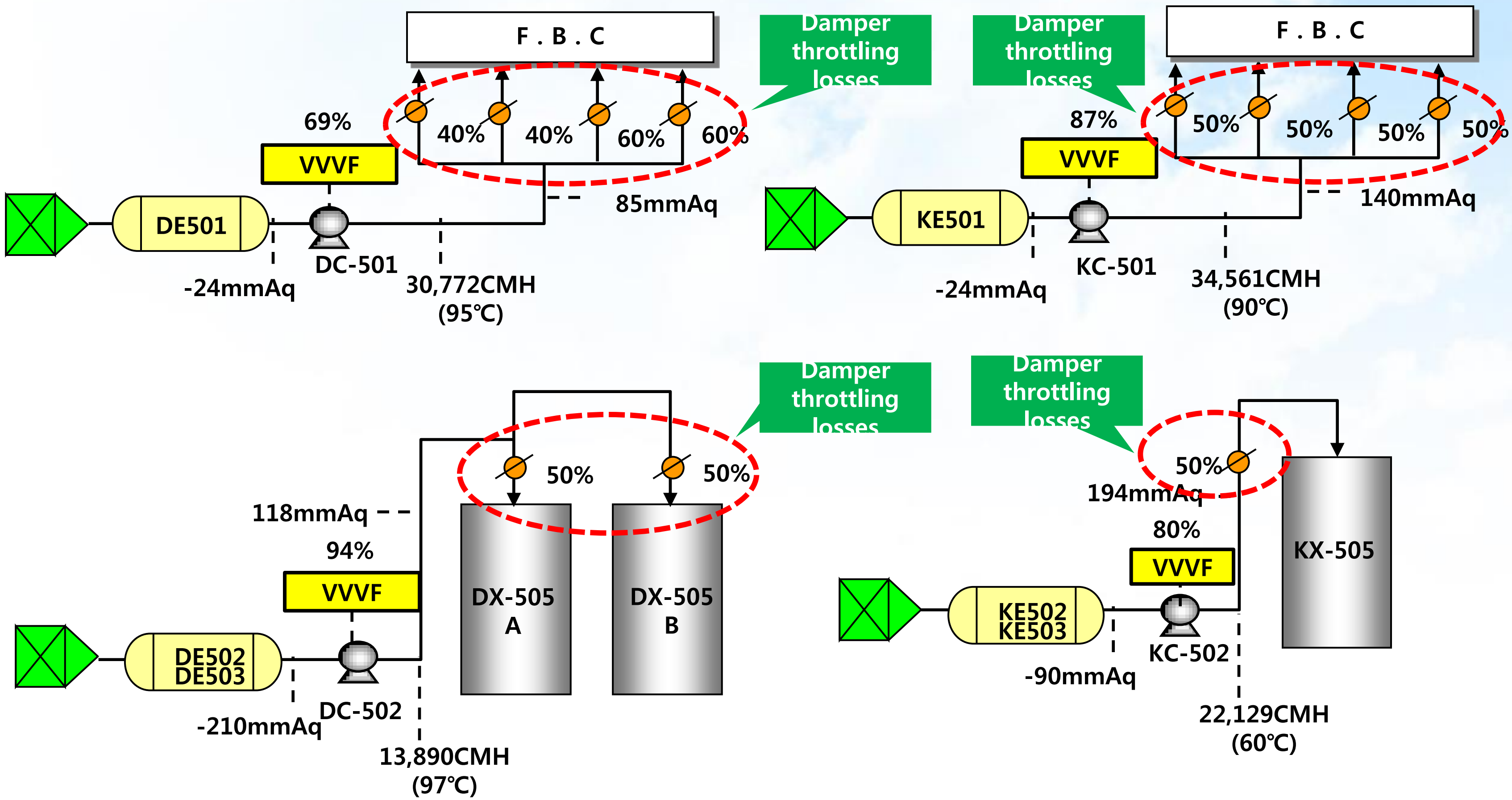
2) Improvement plan

- Improvement plan 1) Auto RPM control by installing inverter
- Improvement plan 2) Fixed RPM control by installing inverter + existing damper control

Case3. Reducing damper loss of supply hot air blower piping system

A. Operation Status

- Driving Schematic



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- damper throttles photo

- Problem Summary

Damper adjustment while operating inverter

Low rate of opening of the damper supply piping system

Loss of A-P of damper throttling

→

Increasing blower driving A-P by unnecessary A-P loss

→

Loss of blower power consumption

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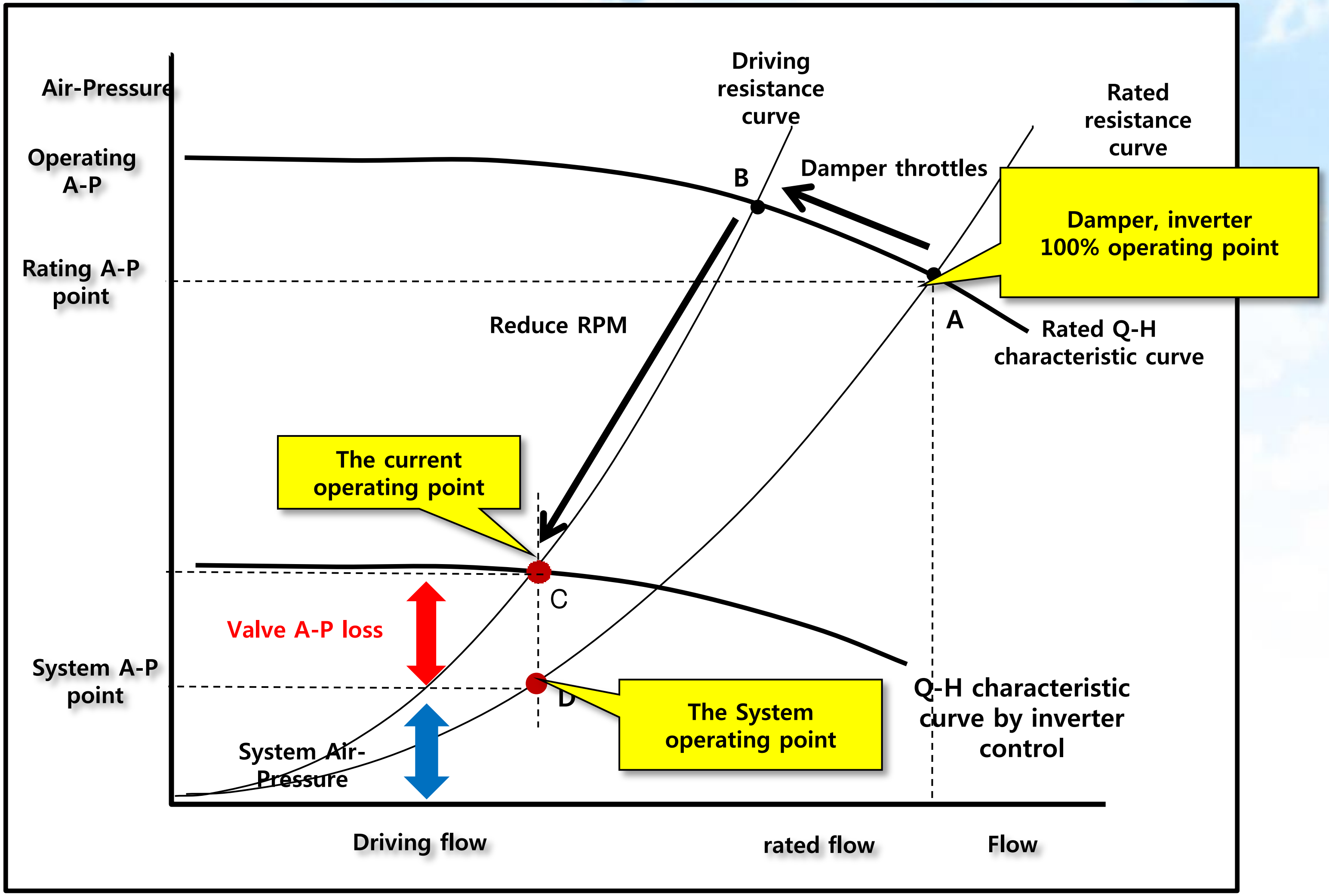
- Analysis loss factor on characteristic curve



B. Improvement perspective and plan

1) Improvement perspective

- Maximum opening rate of system damper
- Lowering standards of supply A-P
- Reduce the number of rotation of inverter while maintaining the same airflow

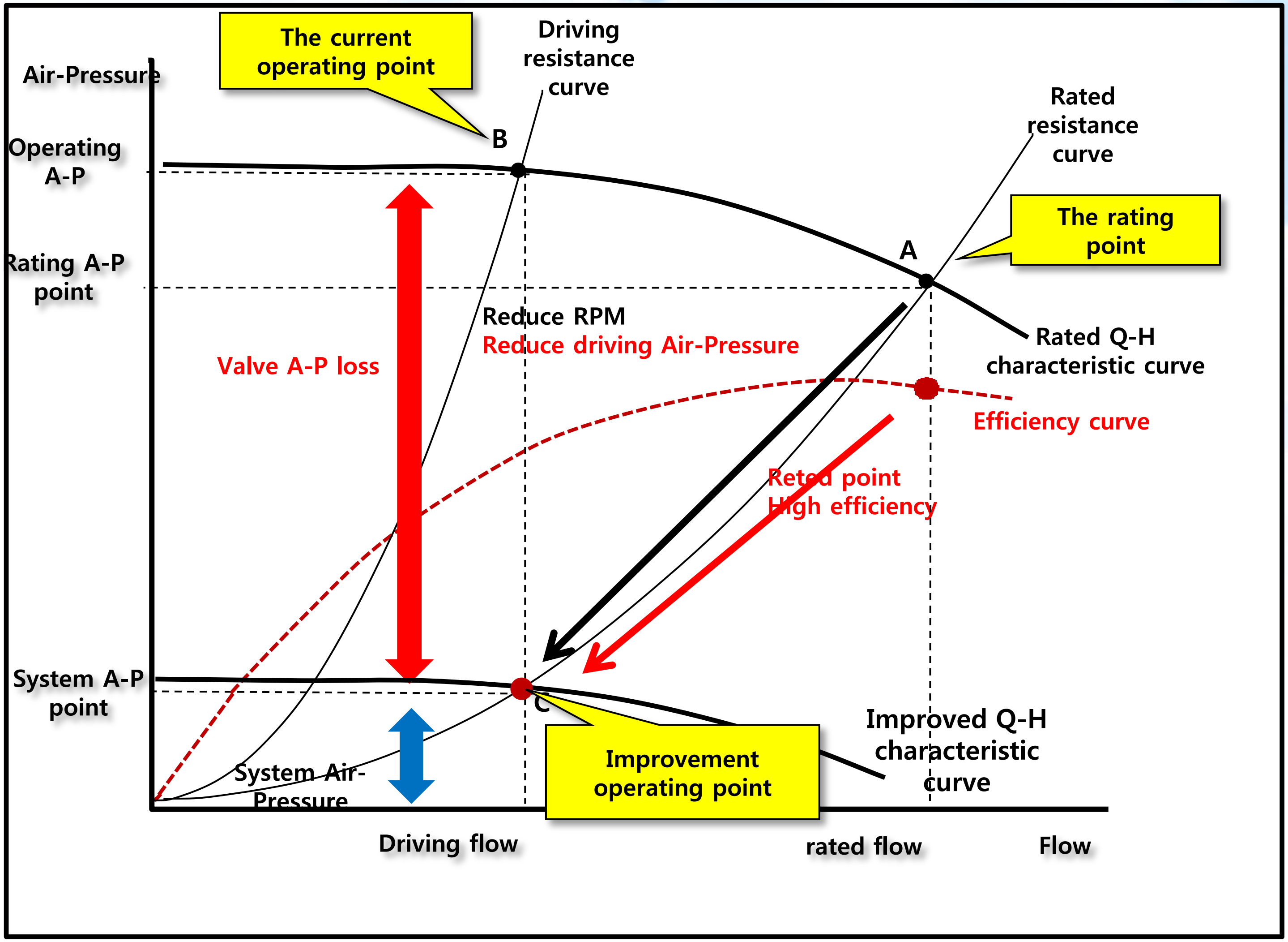
→ Minimizing fan driving A-P and system losses → Reducing blower power consumption

2) Improvement plan

- Improvement plan) Maximum opening rate of system damper + reducing additional inverter rotation

  - Maximum opening rate of The middle of the damper and end of damper
  - reducing additional inverter rotation

- Analysis characteristic curve with inverter



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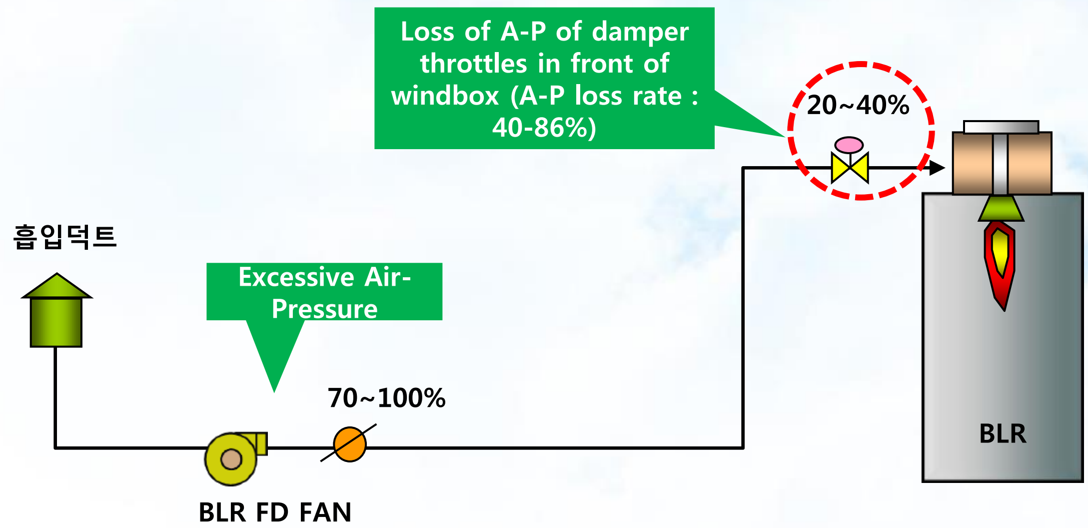
Case4. Reducing loss of damper throttling of BLR F.D fan by Installing inverter

A. Operation Status

- Driving Schematic



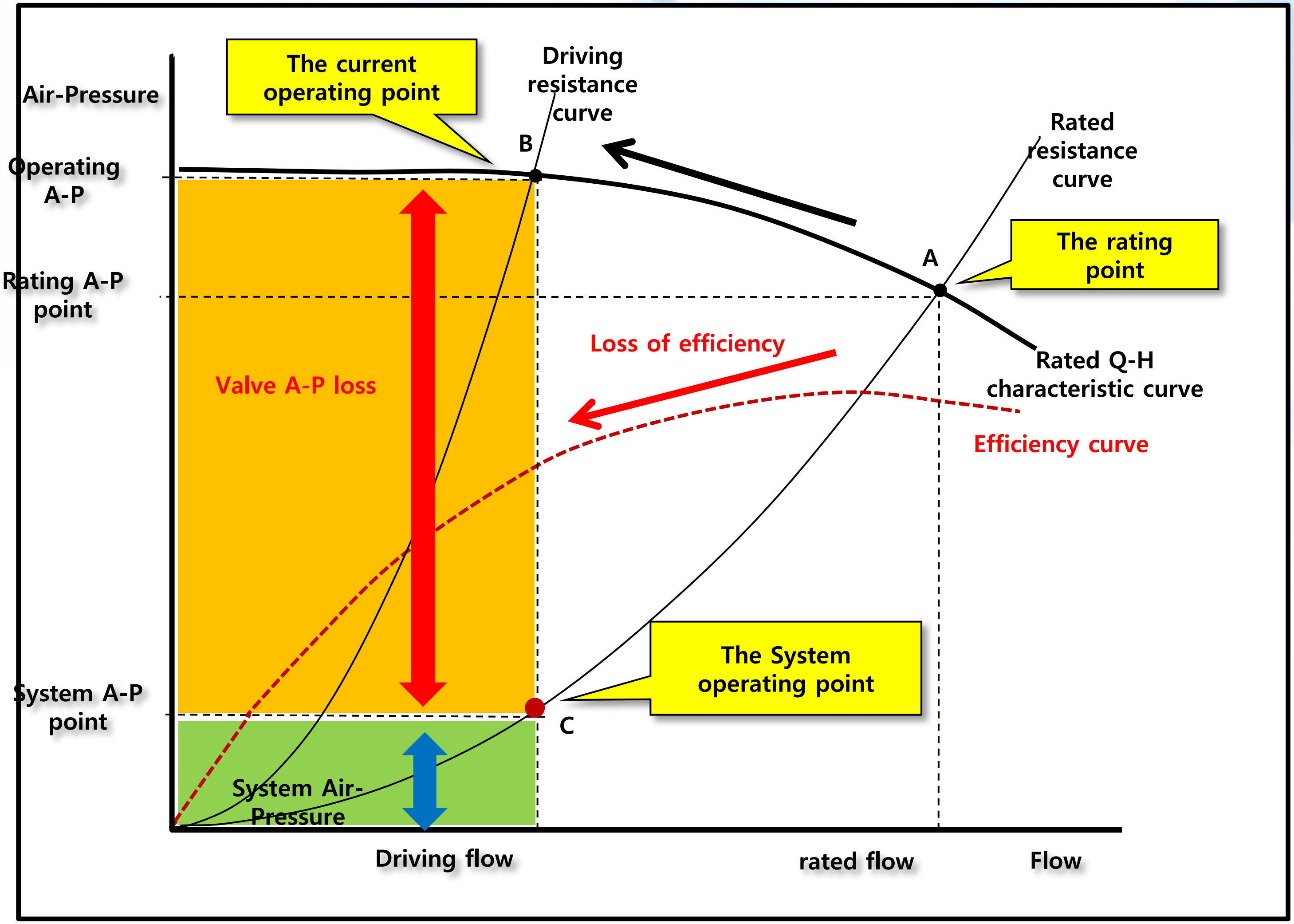
- Problem Summary

Excessive ratings and driving airflow compared to the supply pressure needed

Loss valve throttling because of low automatic valve rate at windbox entrance

→ Unnecessarily excessive A-P of fan → Loss of fan power consumption

- Analysis loss factor on characteristic curve



B. Improvement perspective and plan

1) Improvement perspective

- Optimizing driving A-P FD fan
- Maximum opening rate of auto valve
- Conducting automatic control against load factor changes
- Using air flow control system without loss of A-P

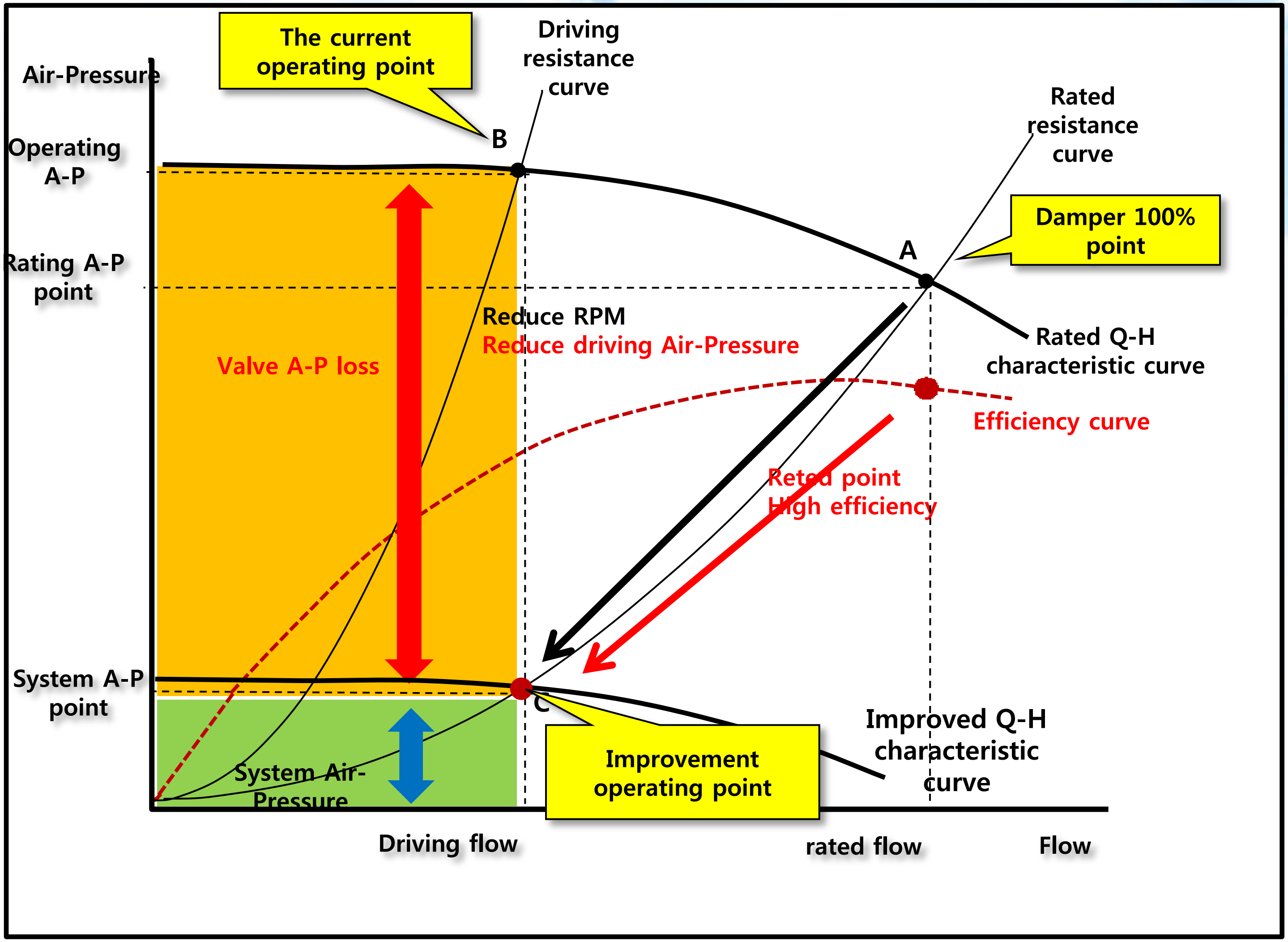
→ Reducing unnecessary driving A-P of fan → Reducing fan power consumption

Install inverter

2) Improvement plan

- Improvement plan 1) Auto RPM control by installing inverter
- Improvement plan 2) Fixed RPM control by installing inverter + existing damper control

- Analysis characteristic curve with inverter



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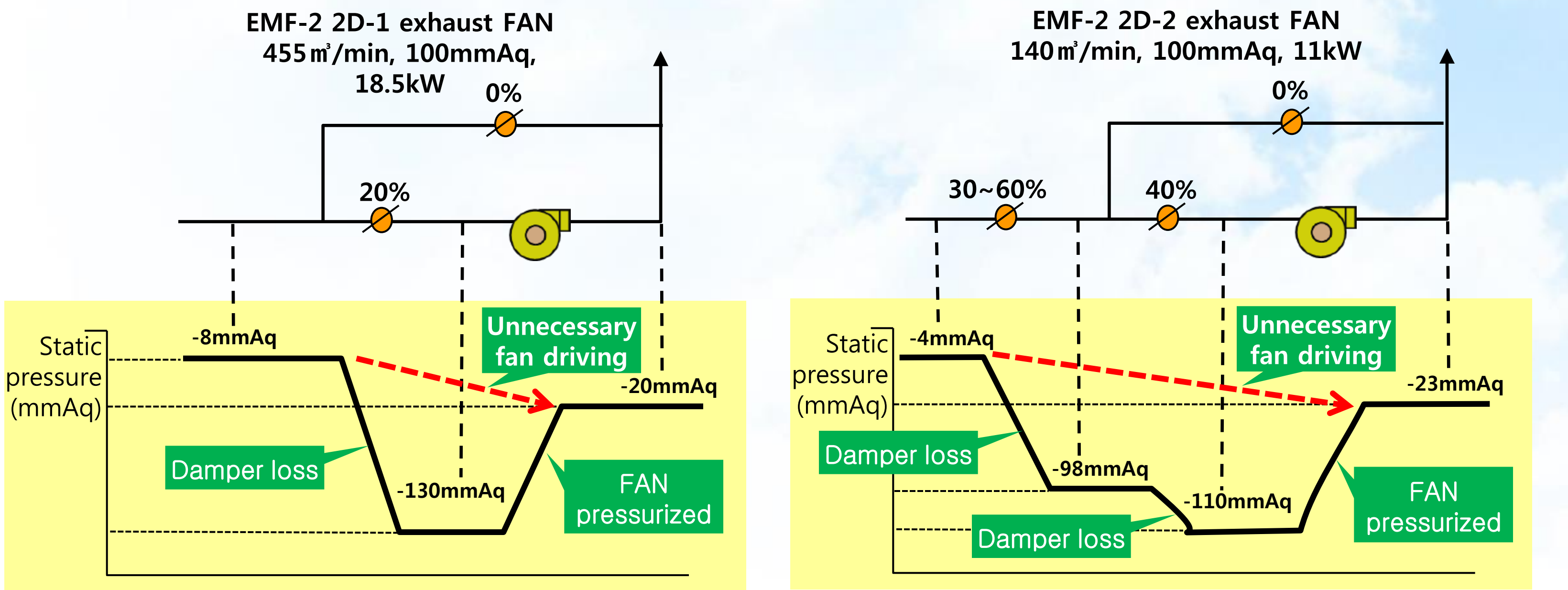
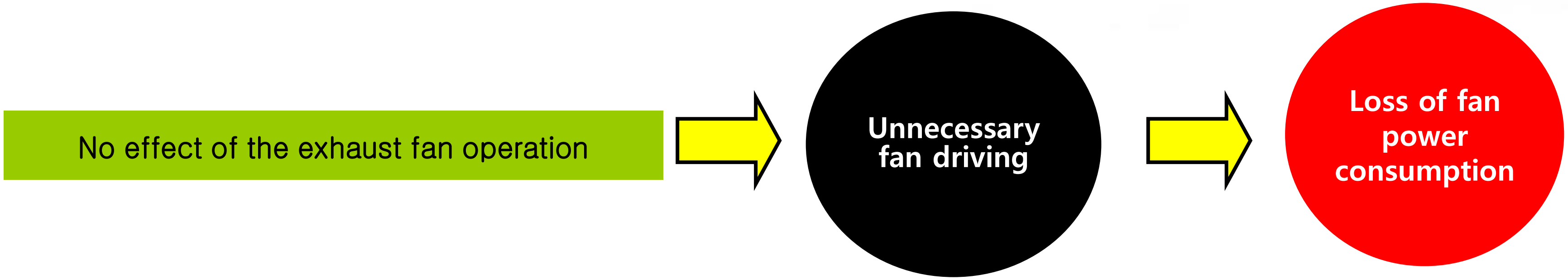
Case5. Check operation efficiency of exhaust fan

A. Operation Status

- Driving Schematic



- Problem Summary



B. Improvement perspective and plan

1) Improvement perspective

Shutdown exhaust fan ineffective

Using existing by-pass line

→ **Remove unnecessary fan driving** → **Reducing fan power consumption**

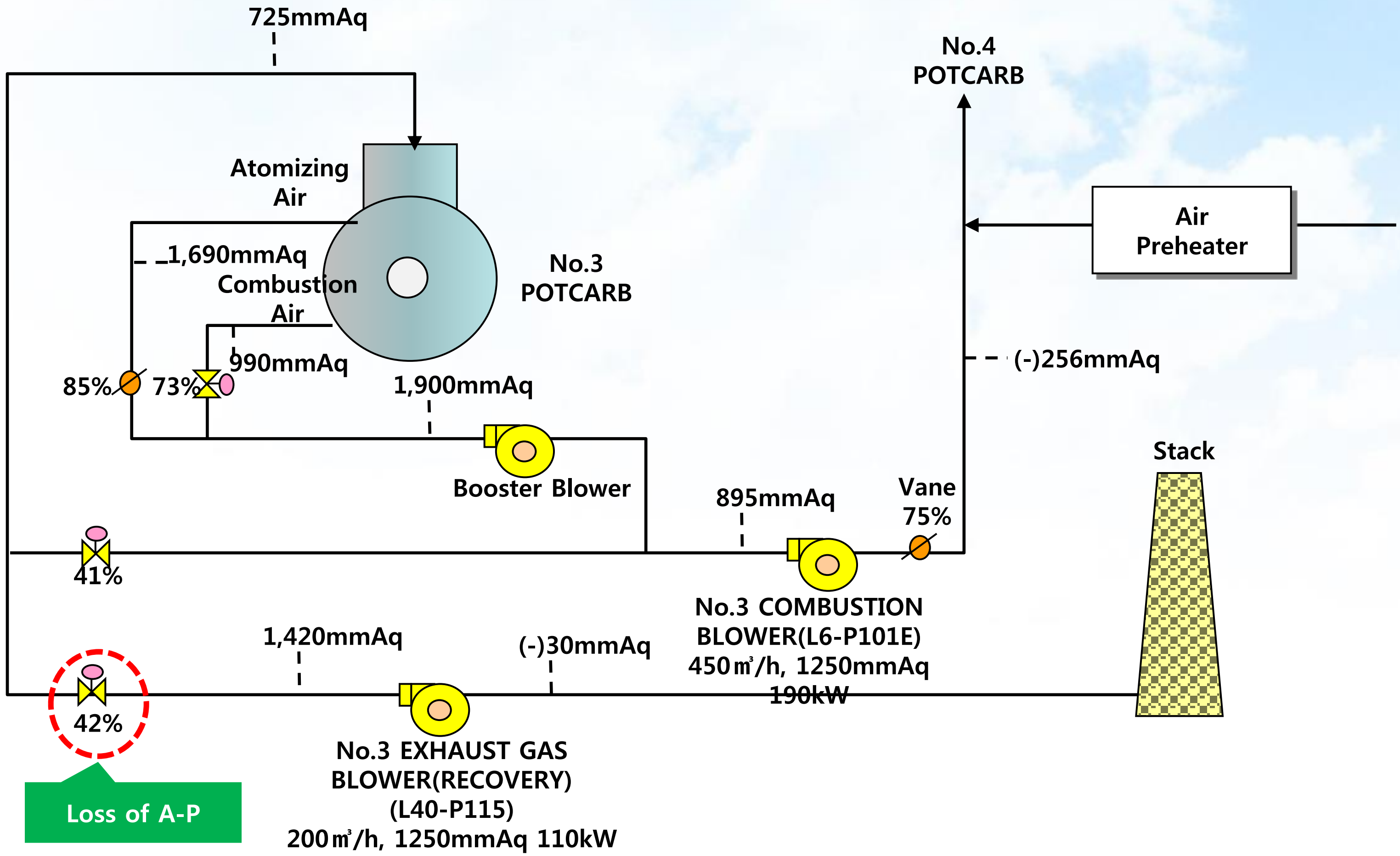
2) Improvement plan

[Improvement plan] EMF-2 2D-1, 2 downtime exhaust fan + use existing by-pass line

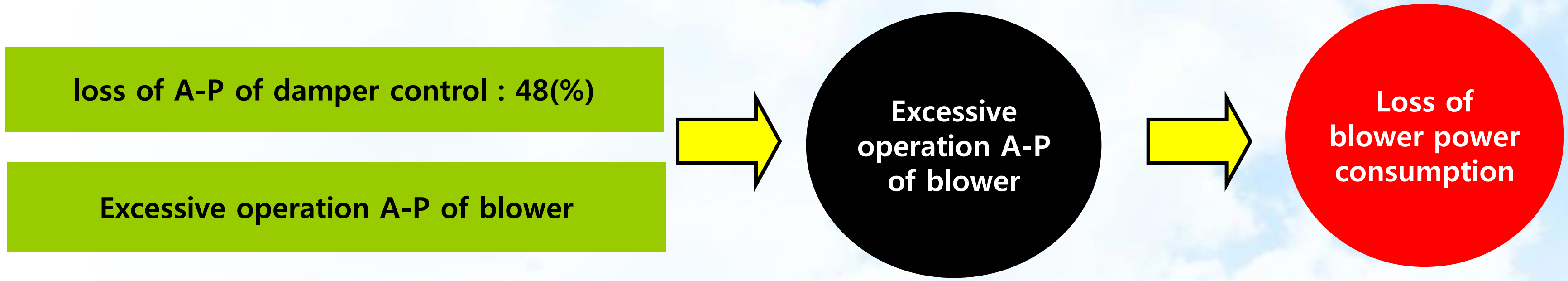
Case6. Reducing loss of AP by installing blower inverter

A. Operation Status and Improvement plan

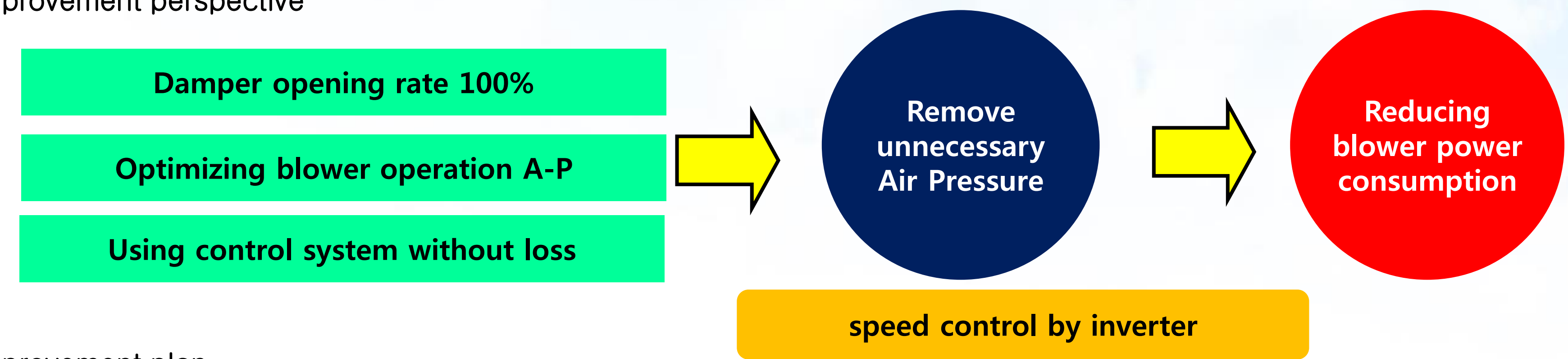
- Driving Schematic



- Problem Summary



- Improvement perspective



- Improvement plan

  - Conducting air flow control by inverter and maintaining 100% opening rate of existing automatic damper.
  - Control inverter by using current control signal of automatic damper.

Case7. Seasonal airflow adjustment by inverter at process C/T FAN

A. Operation Status 및 Improvement plan

- Operation Status
  - One of two process C / T fan is always operating, driving schedule airflow regardless of the out side temperature.
  - Expected excess cooling because of continued operation at the period of low out side temperature.

- Problem Summary

C/T FAN operating year-round

driving schedule airflow regardless of the out side temperature

Excessive operation Air flow of fan

Loss of fan power consumption

- Improvement perspective

Adjustment airflow load factor seasonally

Setting proper airflow load rate according to the out side temperature

Remove unnecessary Air flow

Reducing flow power consumption

2) Improvement plan

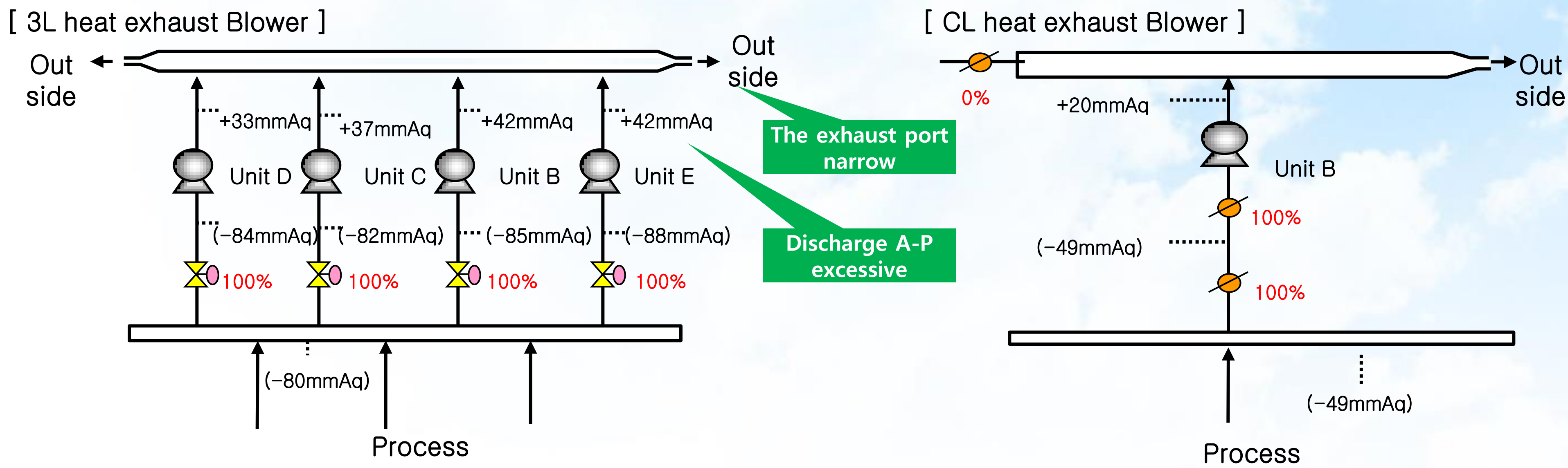
speed control by inverter

- Improvement plan) Adjustment airflow load factor seasonally by inverter

Case8. Expanding discharge port for relieving excessive discharge air pressure of heat exhaust blower

A. Operation Status and Improvement plan

● Driving Schematic



●Improvement plan 1] Install inverter + Make enough discharge port at blower discharge duct

●Improvement plan 2] Replace Pulley + Make enough discharge port at blower discharge duct

●Improvement plan 1] Reduce operation unit + Make enough discharge port at blower discharge duct

Case9. Replacement high efficiency Turbo Blower from wastewater Roots Blower

A. Operation Status and Improvement plan

- Problem Summary

Expected low efficiency operation of Roots Blower

Oversupply based on algebraic control

Low-efficiency operation, Excessive airflow supply

Loss of blower power consumption

- Improvement perspective

Installing Turbo Blower built-in high efficiency inverter

Improving control method

Increasing efficiency, Reducing excessive airflow

Reducing blower power consumption

Replacement high efficiency Turbo Blower

- Improvement plan : Installing Turbo Blower built-in high efficiency inverter
  - Savings from 30 to 40 (%) by driving efficiency and optimization airflow

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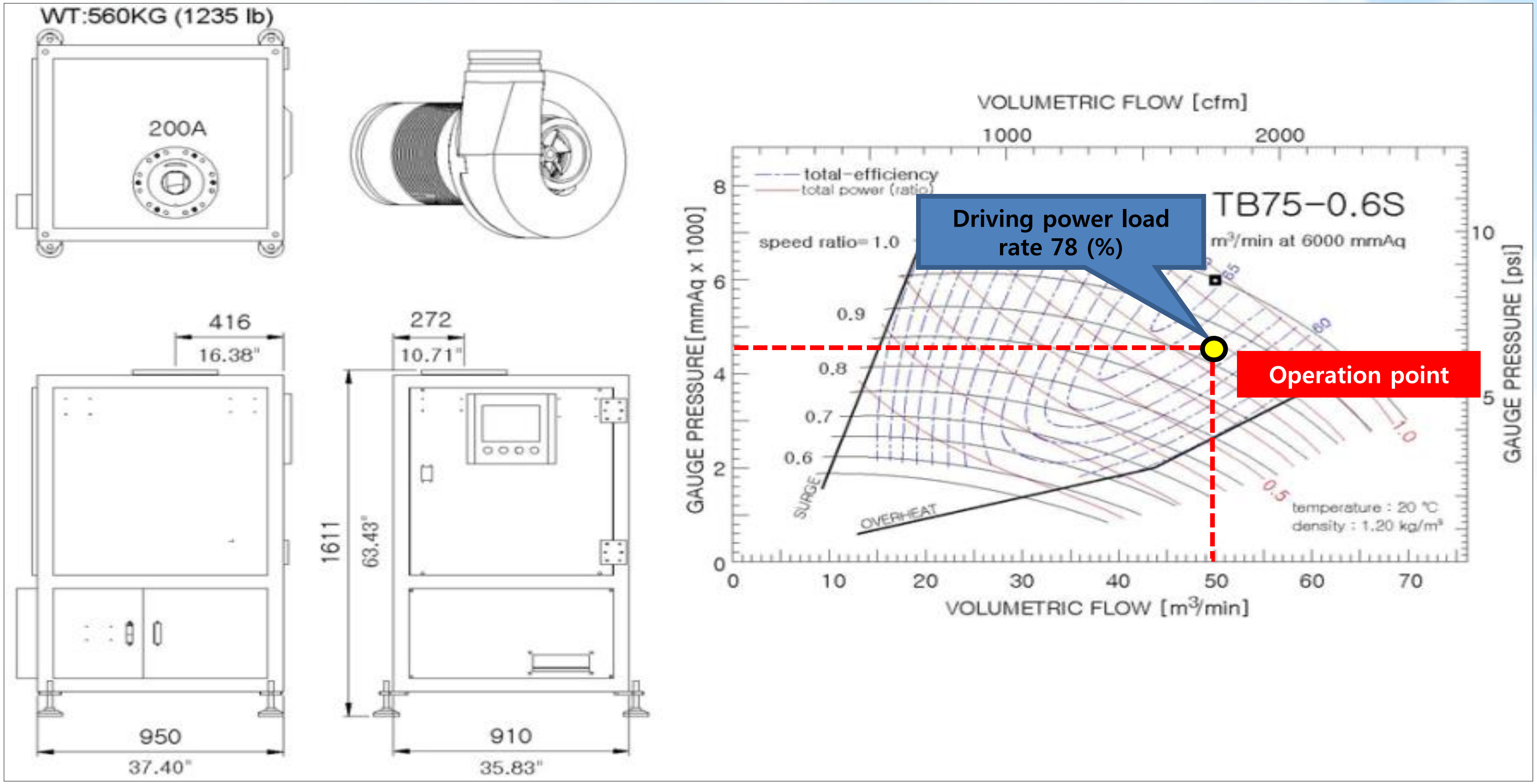
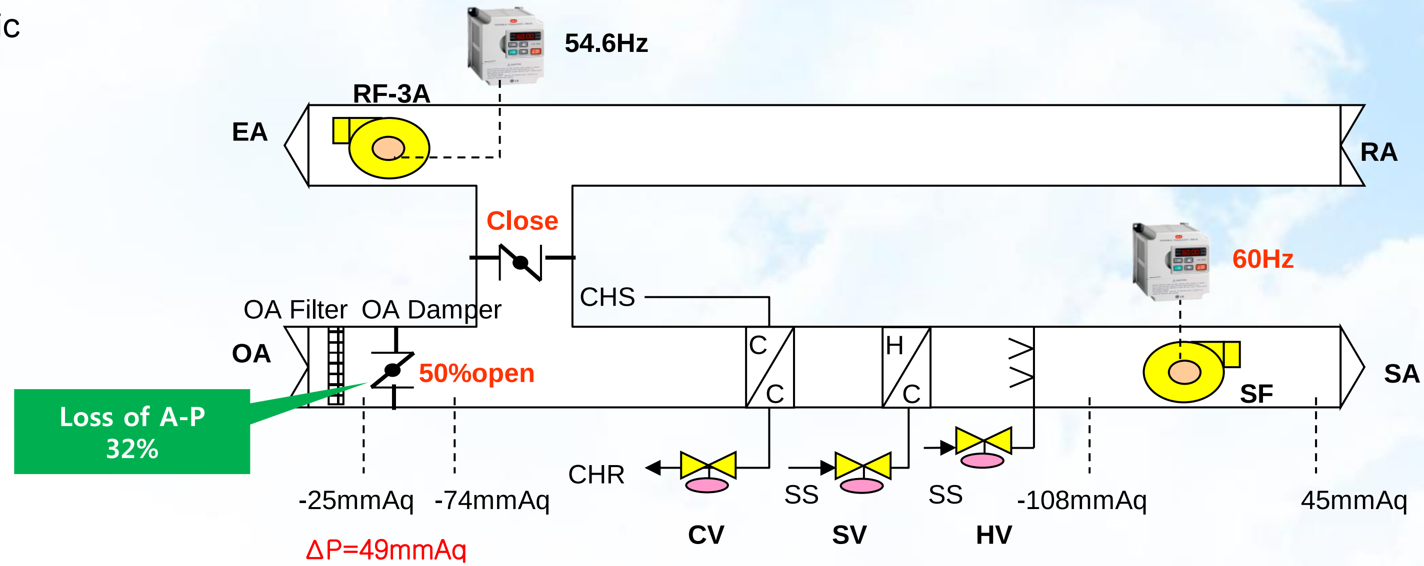
- Characteristic curve of Turbo Blower built-in high efficiency inverter



Case10. Reducing loss of Air-Pressure at AHU OA damper

A. Operation Status and Improvement plan

●Driving Schematic



●Problem Summary

- Loss of Air-Pressure at OA Damper is 49mmAq. (32% loss of the driving Air Pressure)
- Even though the inverter is installed (operating frequency 60Hz), damper is adjusted by the airflow so, it is illogical .

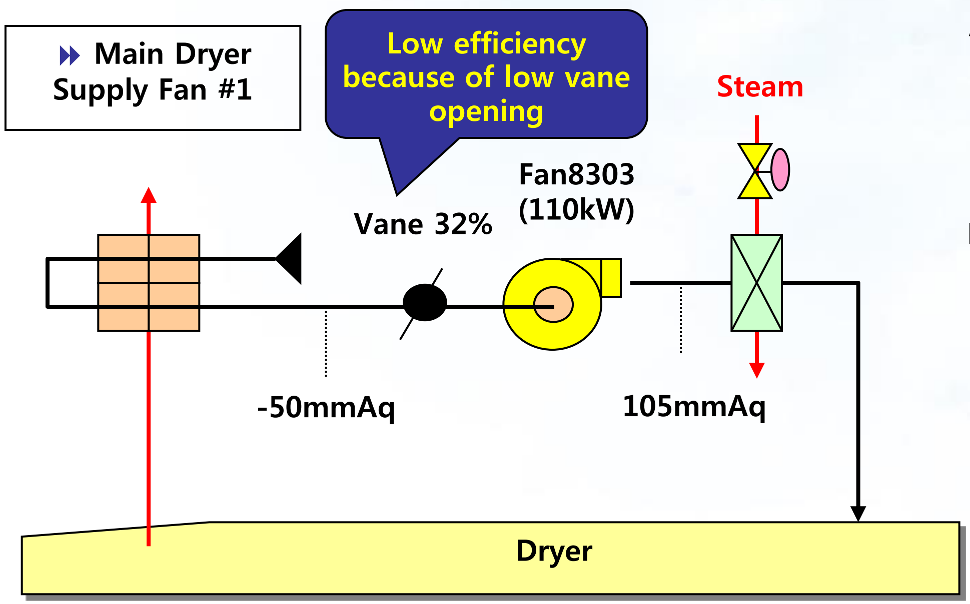
●Improvement plan

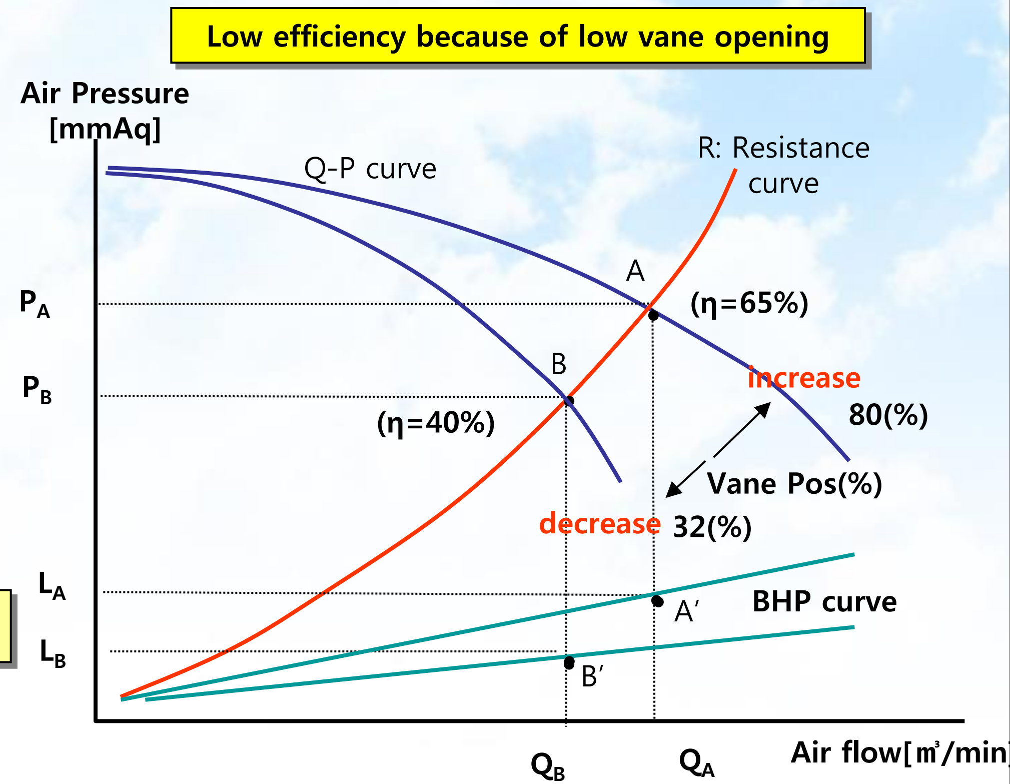
- OA damper full opening and airflow is adjusted by inverter
- Savings the SF consumption power by reducing loss of driving air pressure

Case11. improvement Dryer Supply Fan Vane open

A. Operation Status and Improvement plan

●Driving Schematic





●Improvement plan : Improve vane open + reduce Fan RPM

– Improvement plan 1(reduce Fan RPM) : Pulley adjustment

– Improvement plan 2(reduce Fan RPM) : Inverter installation

Thank you for Listening.

17 JAN. 2018

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New & Renewable Energy Policy Division

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