Resistance Welding

Fundamentals Overview

저항용접의 기본 개요

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1. 저항용접의 개요

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   용접헤드의 종류

4. 파워 서플라이 의 종류 및 특징

Overview

저항 용접의 개요

Resistance Welding Heat Generation
저항용접에서의 열 발생?

Heat is generated by passing an electrical current through the parts (열은 용접시료와 시료 사이를 전류가 통과하면서 발생)

Heat(열) = (I^2 x R x t)/A

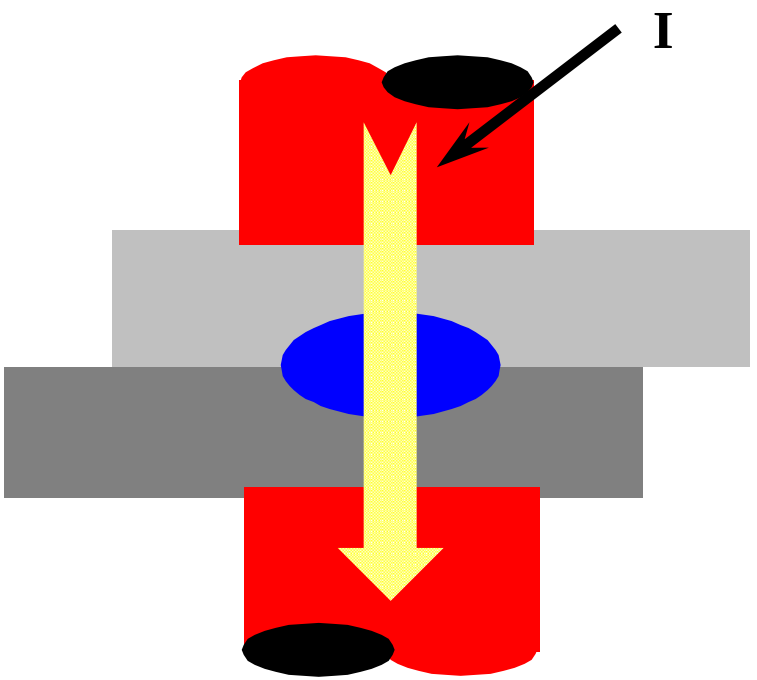
Where:

I=Weld Current(용접전류)

R=Part Electrical Resistance (Ω)
(시료의 전기적 저항)

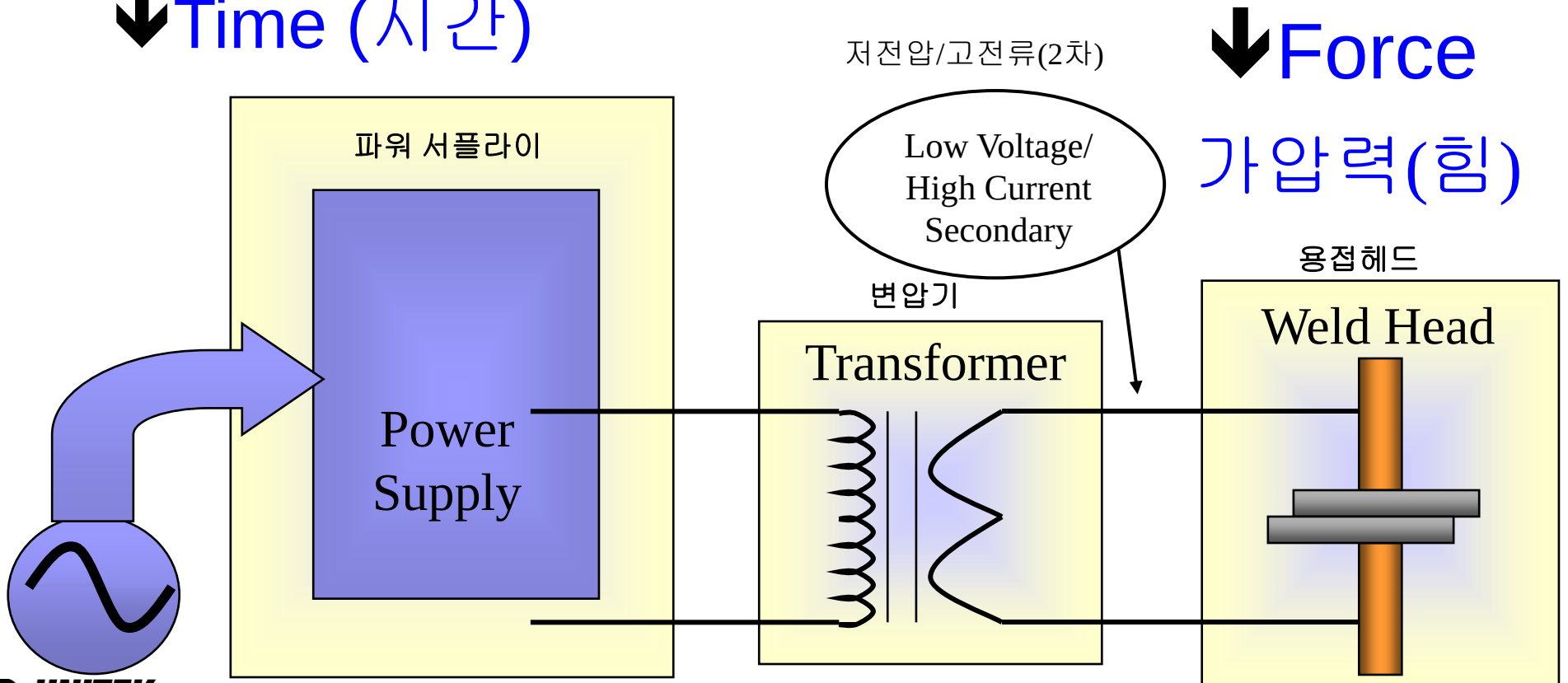
t=Time(용접시간)

A=Electrode Area(전극의 단면적)

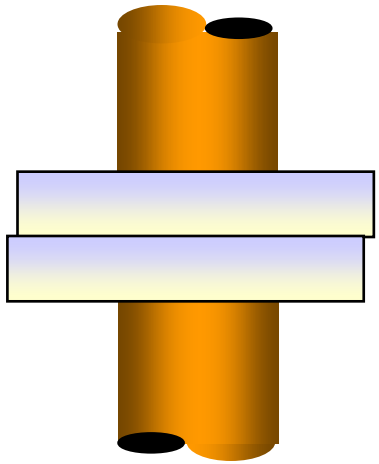


Basic Resistance Welding System
(저항용접의 기본 시스템)

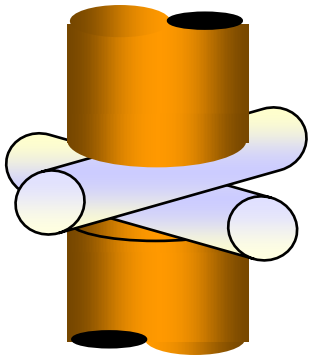
- Weld Current (용접전류)
- Time (시간)
- Force
  가압력(힘)



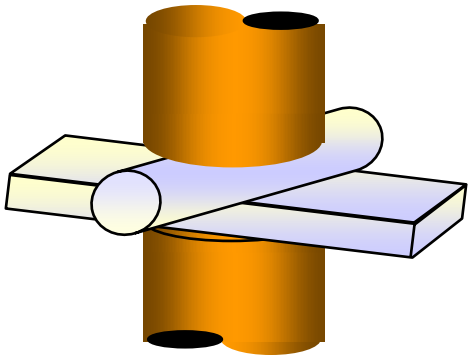
Common Part Geometries (시료 배치)



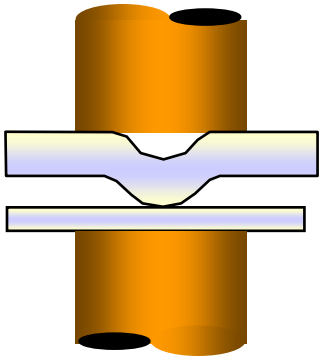
Flat



Round

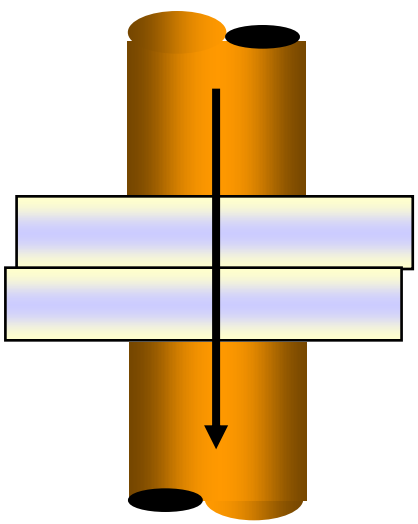


Round /Flat

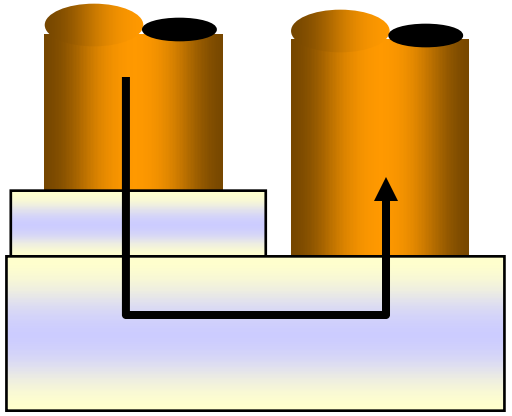


Projection

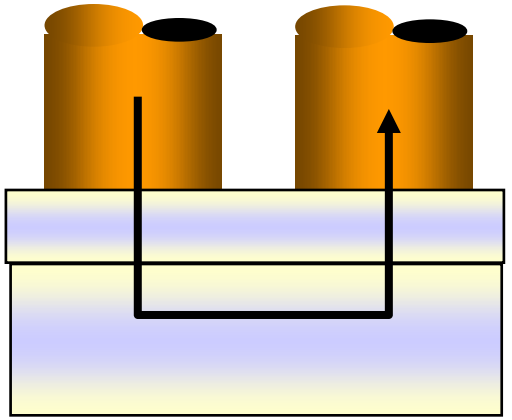
Electrode Configurations (전극 배열)



Opposed
(Direct)

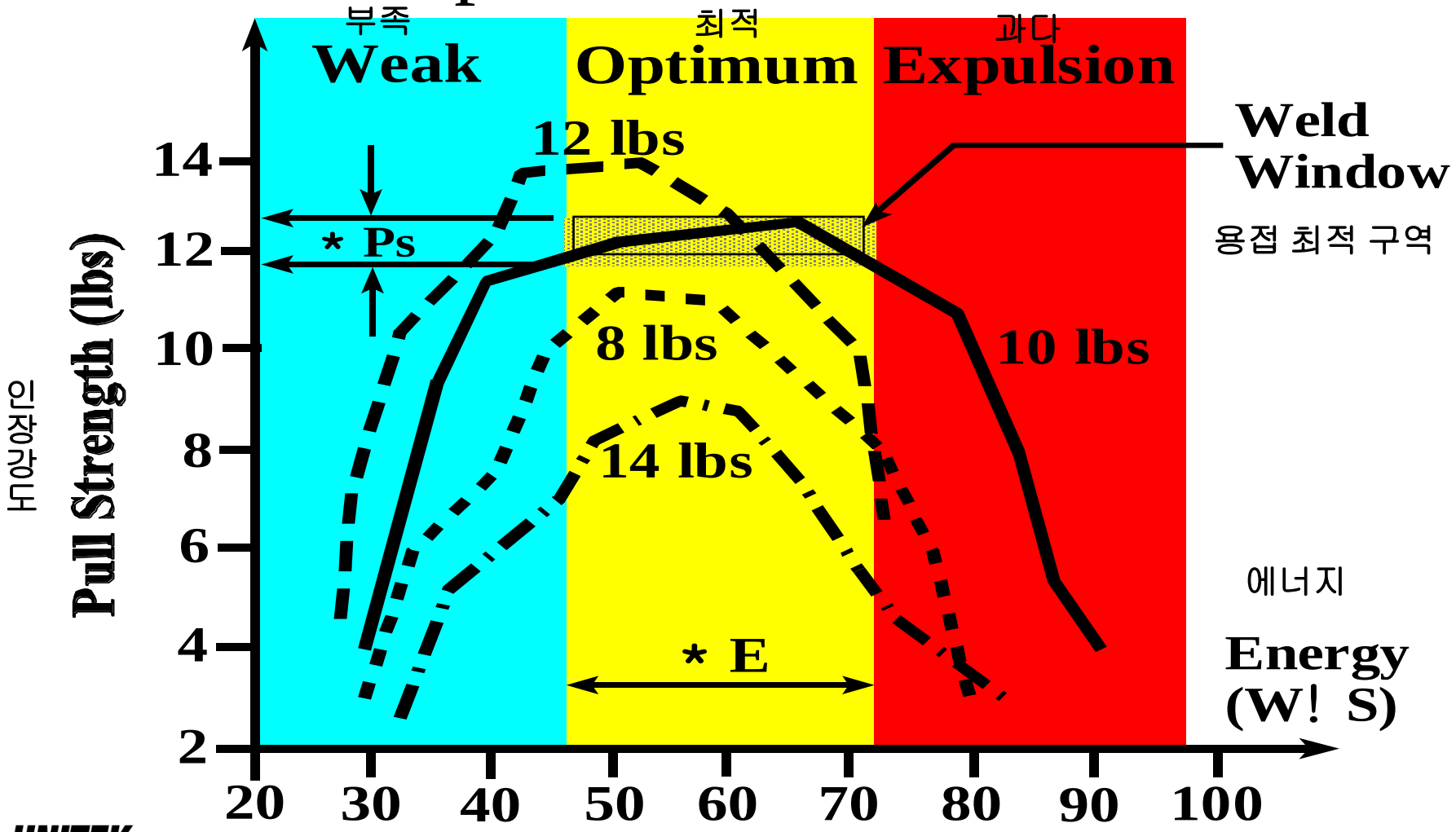


Step Weld
(Indirect)



Series Weld
(Parallel Gap)

Process Optimization (프로세스 최적화)



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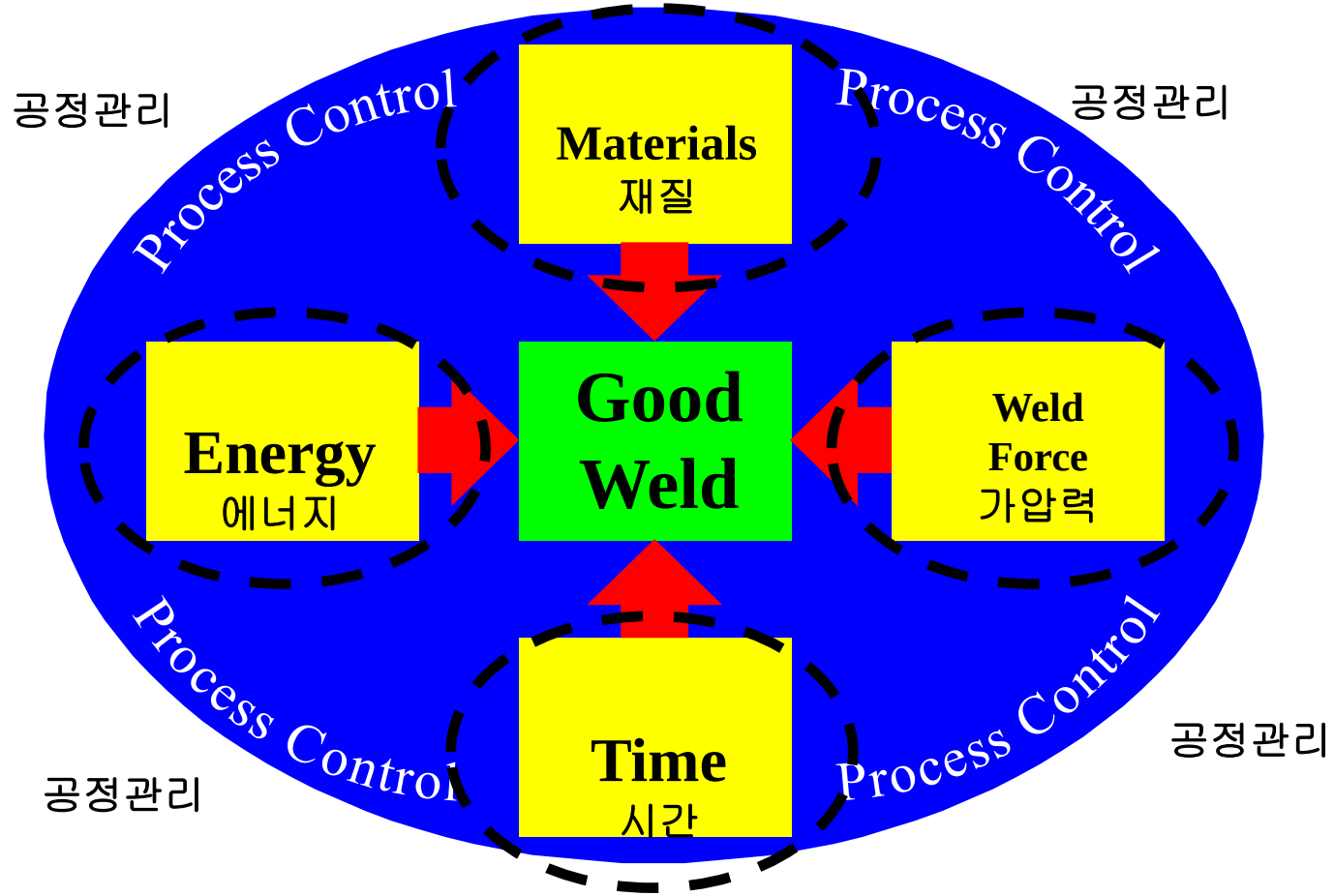
Major Resistance Welding Variables
(저항용접의 주요 변수들)



Electrode

전극의 선택및 관리

Electrode

1. Material Choice (전극 재질)
2. Positioning & Set-up (전극 위치및 배치)
3. Geometry Issues (전극 형상)
4. Cleaning (전극 손질)
5. Current Shunting (전류 분산)

Resistance Categories (저항에 의한 분류)

- Conductive(전도성):

  Silver(Ag,은), Copper(Cu,구리), Gold(Au,금), Aluminum(Al,알루미늄)

- Middle: (반전도성 또는 반저항성)

  Brass

- Resistive(저항성):

  Molybdenum(Mo,몰리브덴), Tungsten(W,텅스텐), Platinum(Pt,백금), Steel(철), Nickel(Ni,니켈), Titanium(Ti,티타늄)

Electrode Material Choice (전극 재질의 선택)
Rule of Opposites (서로 상반되는 규칙을 갖음)

- Conductive electrodes against resistive parts.
  (저항성 부품들에는 전도성 전극이 적합)
- Resistive electrodes against conductive parts.
  (전도성 부품들에는 저항성 전극이 적합)

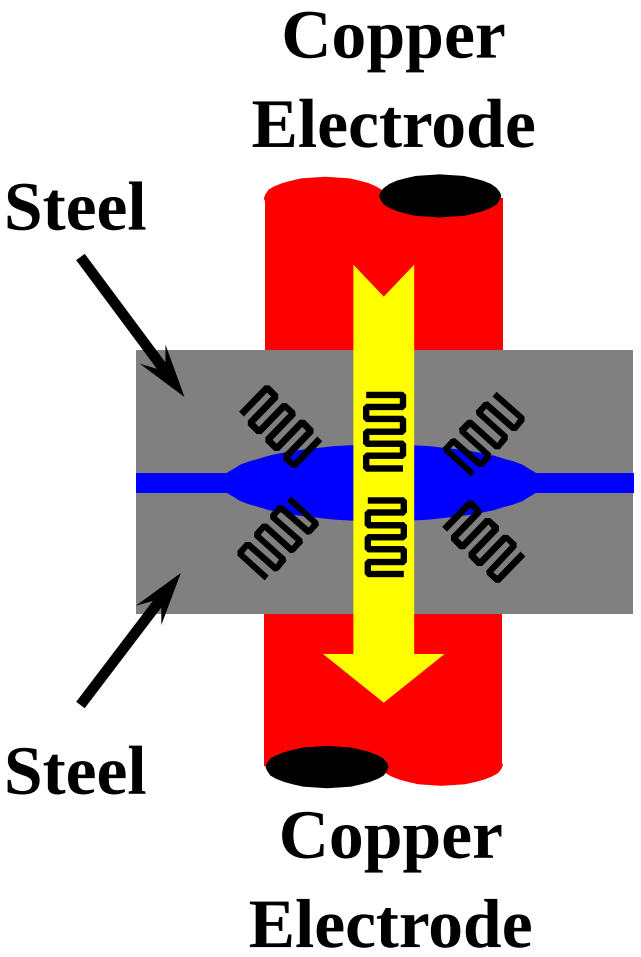
(*Note: Aluminum and Beryllium Copper both break the rule!)*
(알루미늄과 베릴륨 Copper는 위 규칙들에 예외이다)

Thermally Resistive Parts (열 저항성 부품)

Electrically and thermally resistive parts

(전기적, 열적 저항성 부품)

- Internal heat generation (내부 열 발생)
- Conductive (copper) electrodes on resistive parts (steel)
  (저항성 시료에는 전도성 전극이 적합)



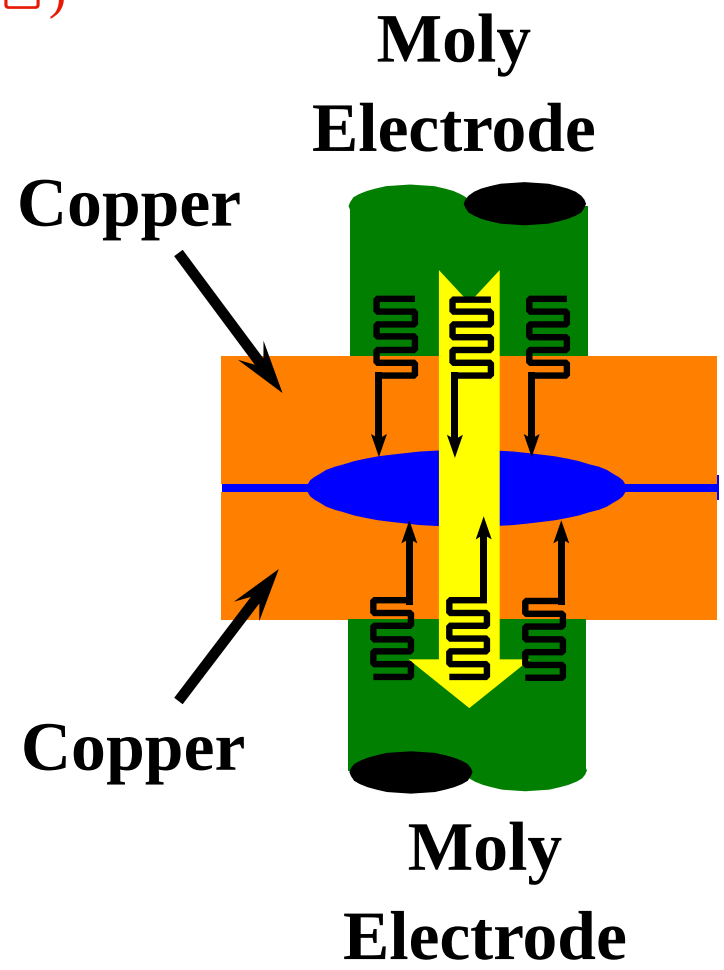
Thermally Conductive Parts (열 전도성 부품)

Electrically and thermally conductive parts

(전기적, 열적 전도성 부품)

- External heat generation(외부 열발생)
- Resistive (moly) electrodes on conductive parts (copper)

  (전도성 시료에는 저항성 전극이 적합)

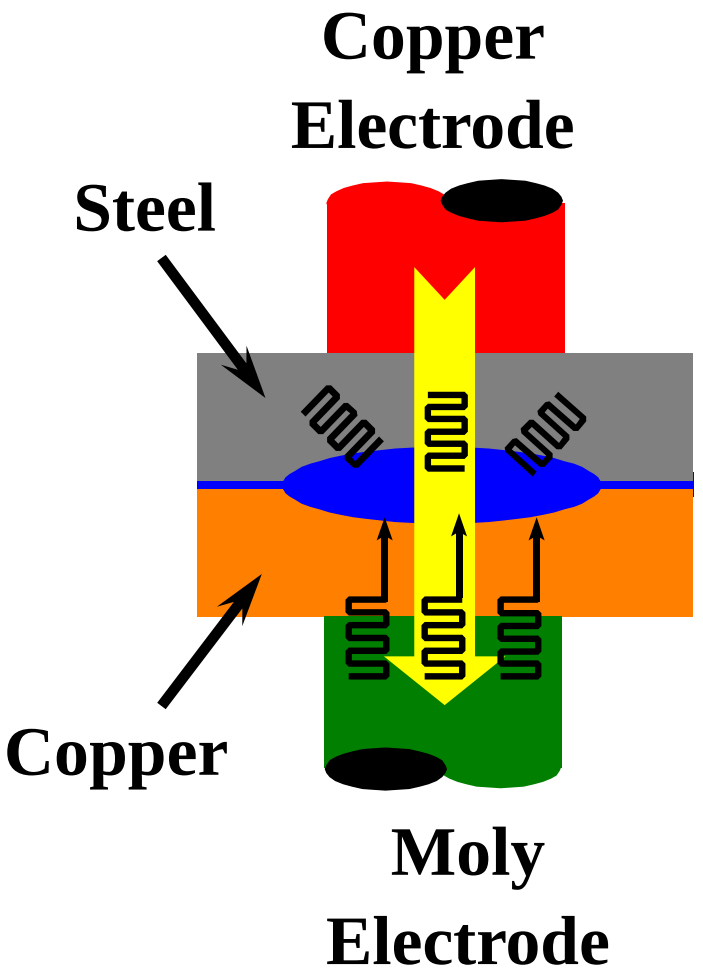


Thermally Mixed Parts (열적 혼합 부품)

Resistive and conductive parts

(저항성 & 전도성 부품)

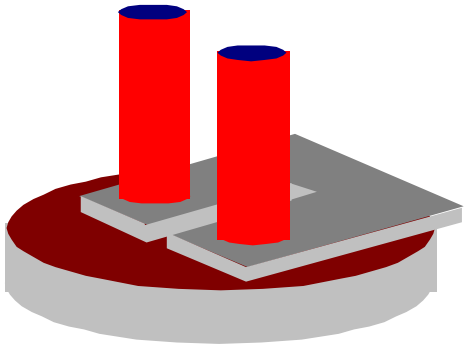
- Combination of internal and external heat generation (외부와 내부 열의 조합)
- Conductive electrodes(copper) on resistive part (steel)
  (저항성 시료쪽에는 전도성 전극)
- Resistive electrode (moly) on conductive part (copper)
  (전도성 시료쪽에는 저항성 전극)



Electrode type (전극 종류)

Material (재질)	Description (성분)	Conductivity (전도율)	Hardness (Rockwell) (경도)
Glidcop AL-15	**Dispersion Strengthened Copper (0.15% Al Oxide) 분산강화 구리**	**92%**	**68B**
RWMA 2	**Copper Chromium 구리 + 크롬**	**85%**	**83B**
RWMA 3	**Copper Cobalt Beryllium 구리 + 코발트 + 베릴륨**	**48%**	**100B**
RWMA 11	**Copper Tungsten 구리 + 텅스텐**	**46%**	**99B**
RWMA 13	**Tungsten 텅스텐**	**32%**	**70A**
RWMA 14	**Molybdenum 몰리브덴**	**31%**	**90B**

2. Electrode Positioning & Set-up



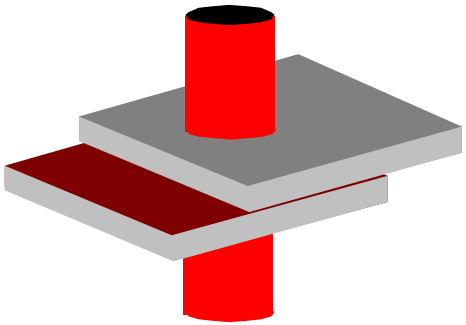
Good!

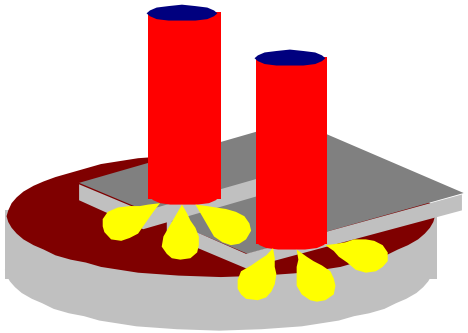
Center Electrodes over parts

(중앙에 위치한 전극) =

No expulsion

(변형이 없다)





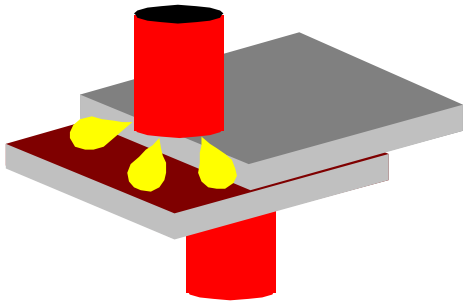
Bad!

Position electrodes over edge

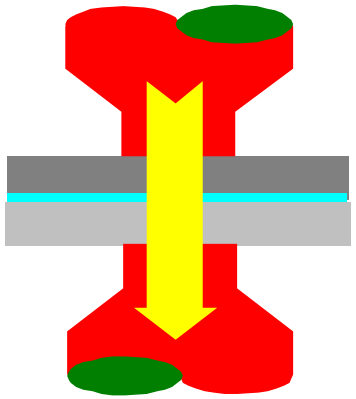
(가장자리에 위치한 전극) =

Expulsion!

(변형이 생긴다)



2. Electrode Positioning & Set-up

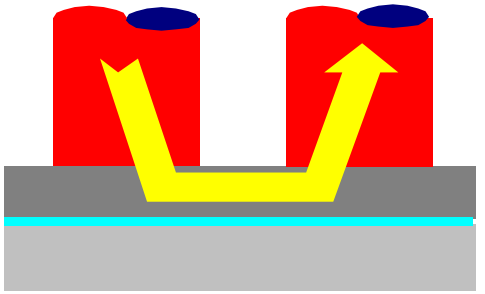


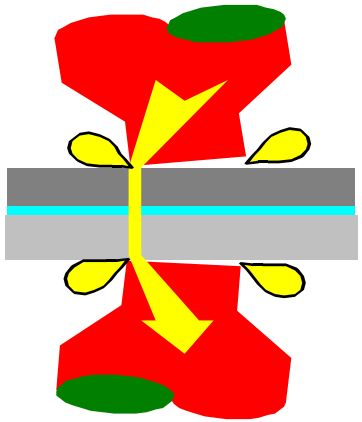
Good!

Full area contact (전면접촉)

Controlled gap (제어된 간격)

Perpendicular (수직 유지)

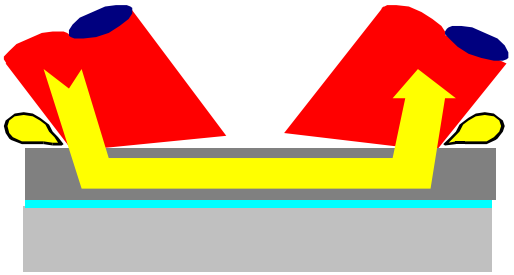




Bad!

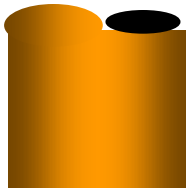
Angled to parts (부품간 각생성)

No gap control (간격 제어 불능)

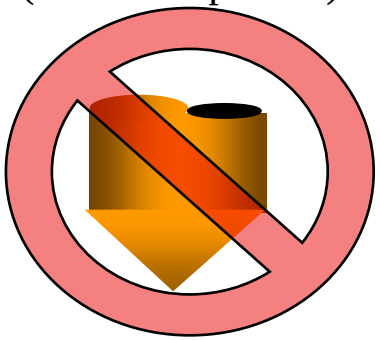


3. Electrode Geometry Issues

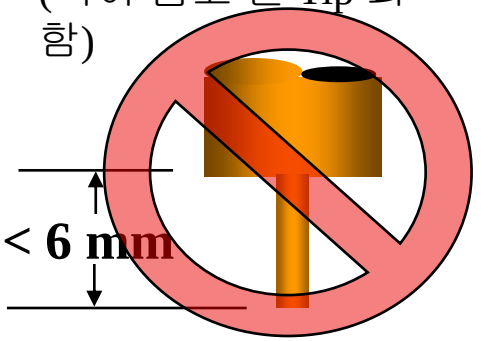
Use constant area tip design
(일정 면적 Tip 사용)



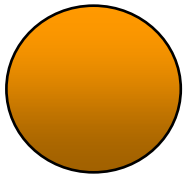
Avoid pointed tip design
(뾰족한 Tip 피함)



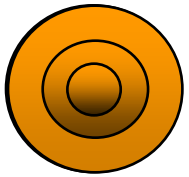
Avoid long narrow tips
(폭이 좁고 긴 Tip 피함)



Electrode face after cleaning(Cleaning 후 전극 표면):

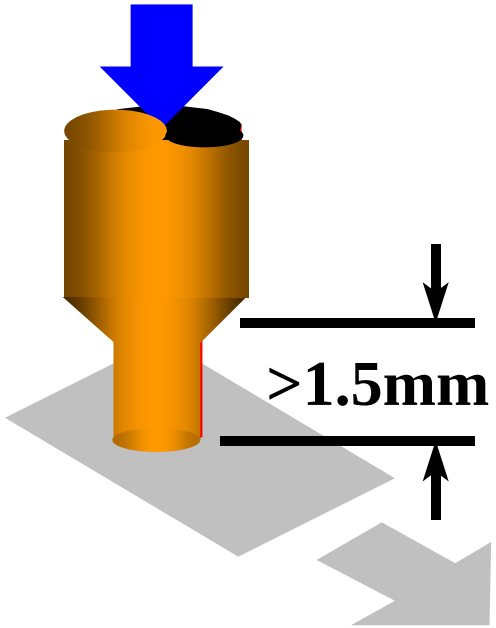


No change in heating
(열에 의한 변화 없음)



Increasing area(면적의 증가) = colder weld(냉용접 유발)

Electrode Cleaning Issues (전극 Cleaning의 주안점)



- Use #600 or finer silicon carbide paper

  (#600 or 실리콘 카바이드 paper 사용)

- Use light electrode force

  (약한 전극 하중 사용)

- Pull grit paper in one direction only

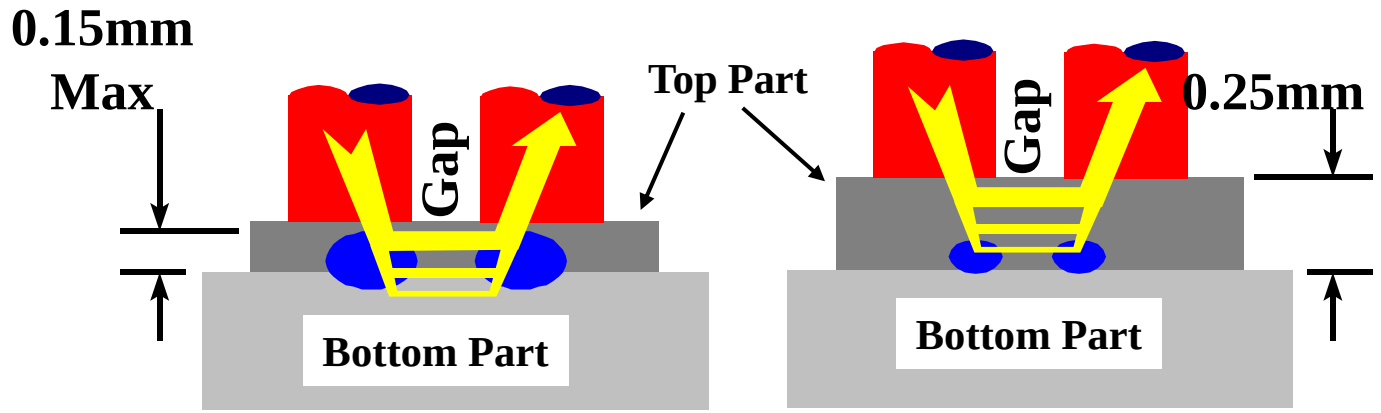
  (오직 한 방향으로 paper를 잡아 당김)

- Replace electrode when tip is less than 1.5mm (.062”) long

  (Tip의 길이가 1.5mm보다 작아지면 전극 교체)

5. Current Shunting

Parallel Gap or Series Weld

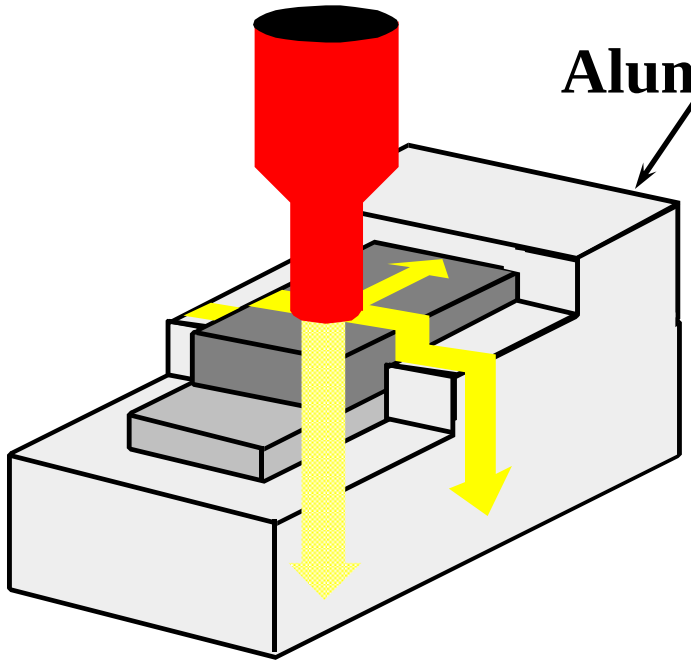


- ☐ Limited to 0.15mm(.006in) thickness
  (0.15mm 두께로 제한)
- ☐ Thinner top part provides more control
  (위쪽 시료가 얇을 수록 작업이 쉽다)
- ☐ Weld current does not reach bottom part
  (용접 전류가 아래쪽 시료까지 도달하지 못한다)
- ☐ Increasing the weld current causes the top part to blow out
  (용접 전류를 증가해도 위쪽 시료로만 흐른다)

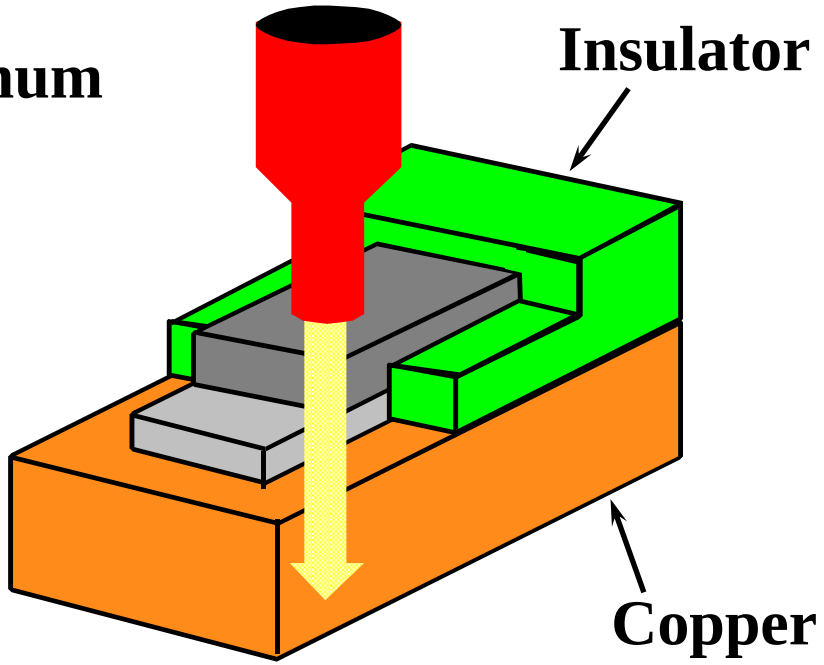
5. Current Shunting

Bad fixture design causes weld current shunting

(잘못된 설비 디자인은 용접 전류를 분산 시킨다)



Four current paths(4개의 전류 통로) =
Inconsistent welds (일정치 않은 용접)



One current path(한 개의 전류 통로) =
Consistent welds (일괄된 용접)

Weld Force

용접 가압력의 중요성및
용접헤드의 종류

Weld Force

1. Weld force affects
(용접 가압력의 영향)

2. Weld head function
(용접헤드의 기능)

3. Weld head actuation
(용접헤드의 동작)

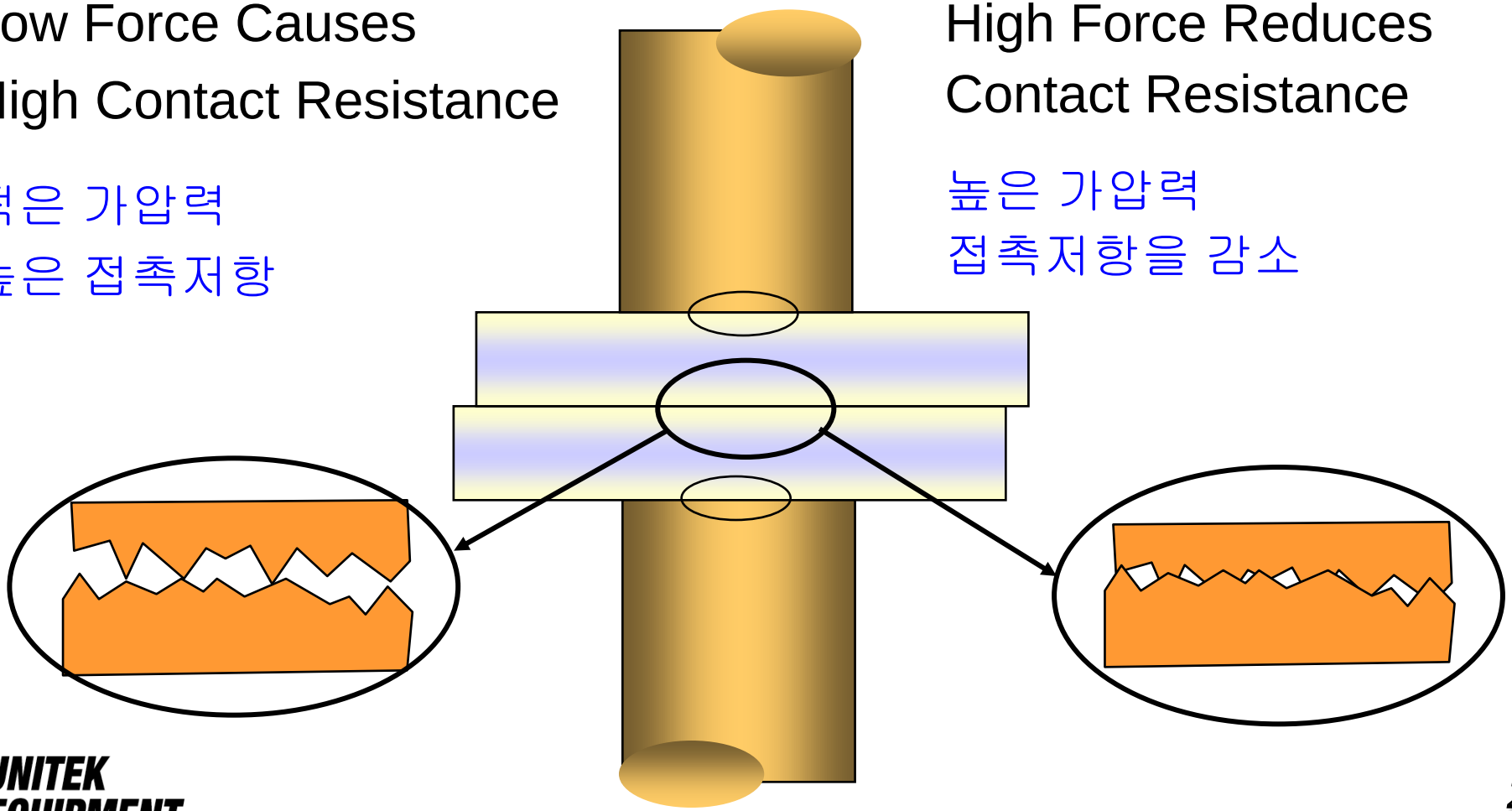
Contact Resistance (접촉 저항)

Low Force Causes
High Contact Resistance

적은 가압력
높은 접촉저항

High Force Reduces
Contact Resistance

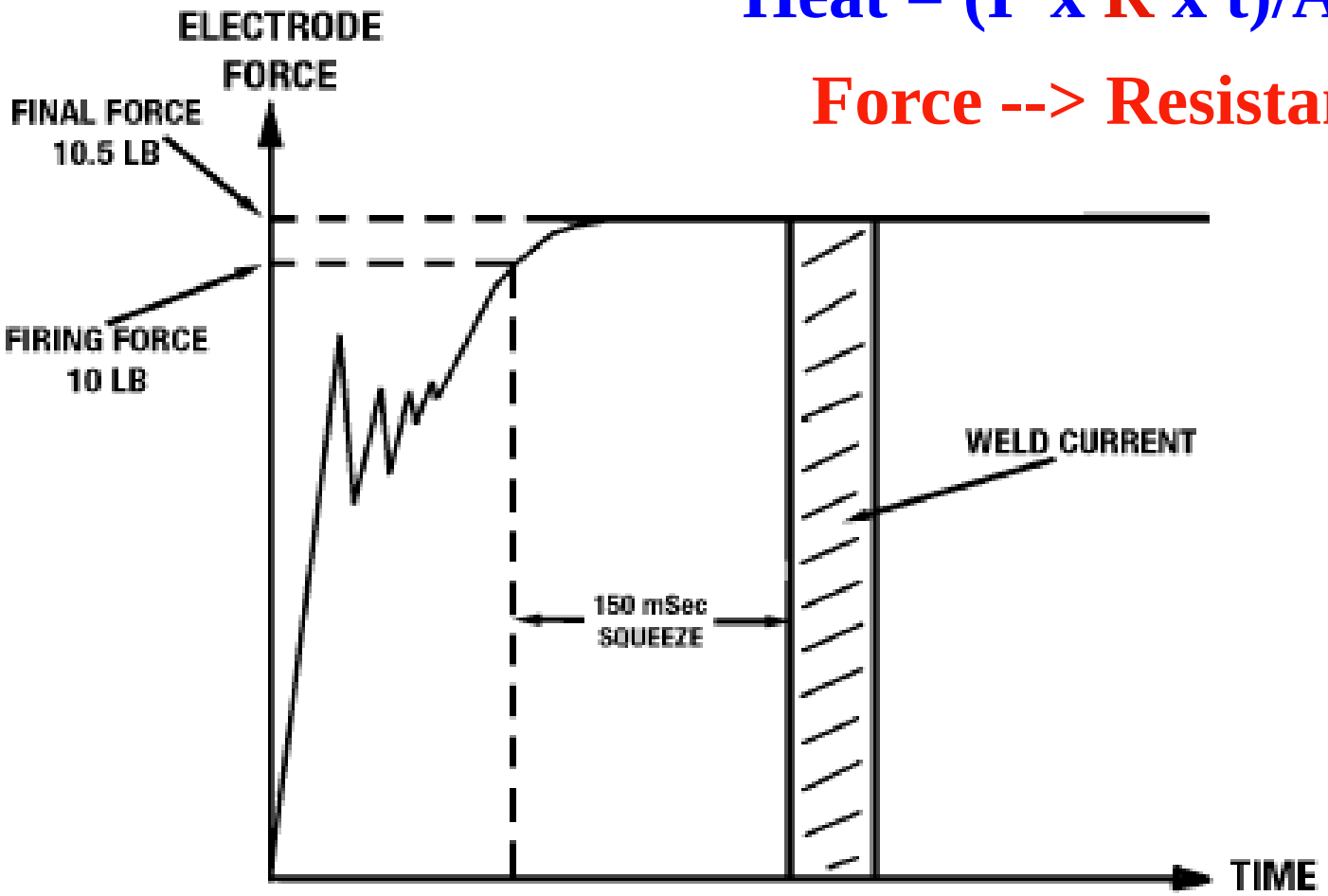
높은 가압력
접촉저항을 감소



Ideal Force Firing (이상적인 가압력 구동)

Heat = (I^2 x R x t)/A

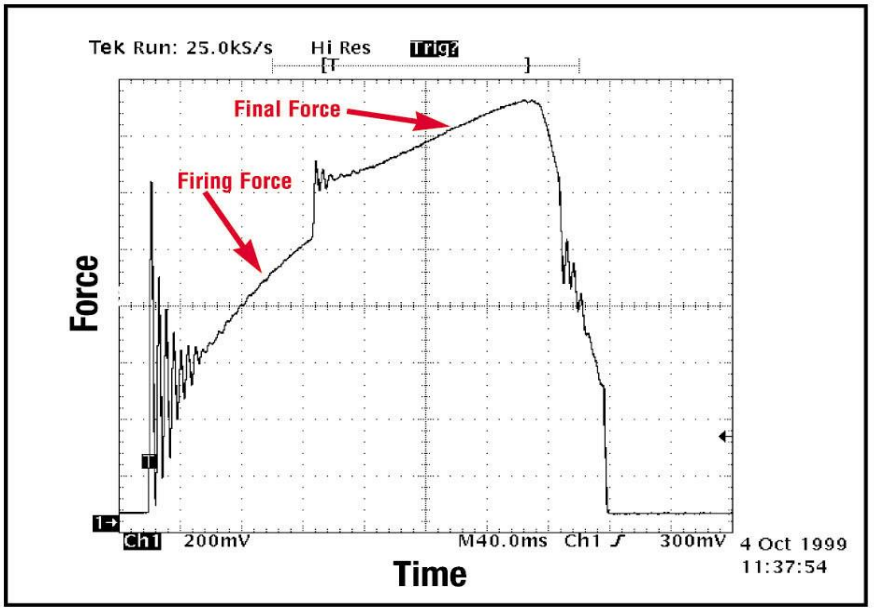
Force --> Resistance

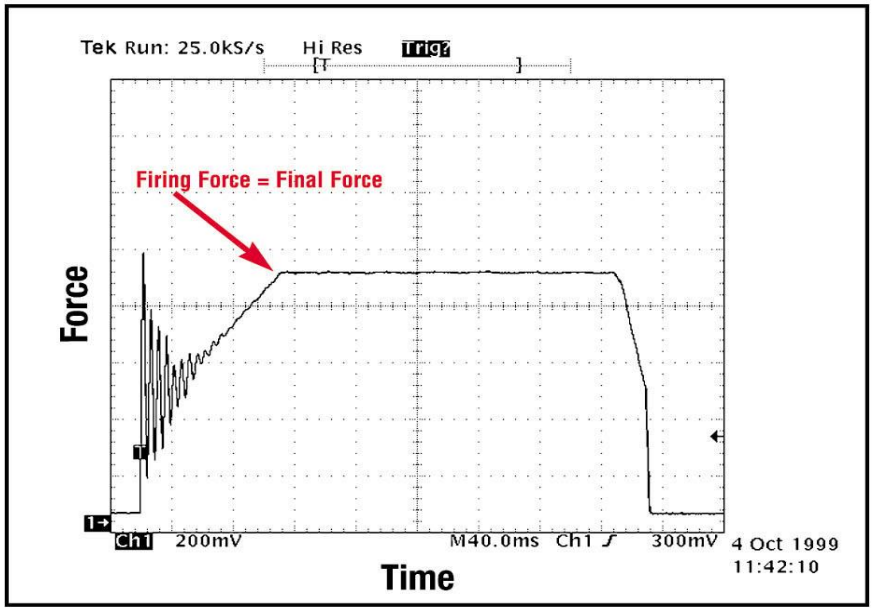


Poor Weld Force Control (용접 가압력이 맞지 않으면)

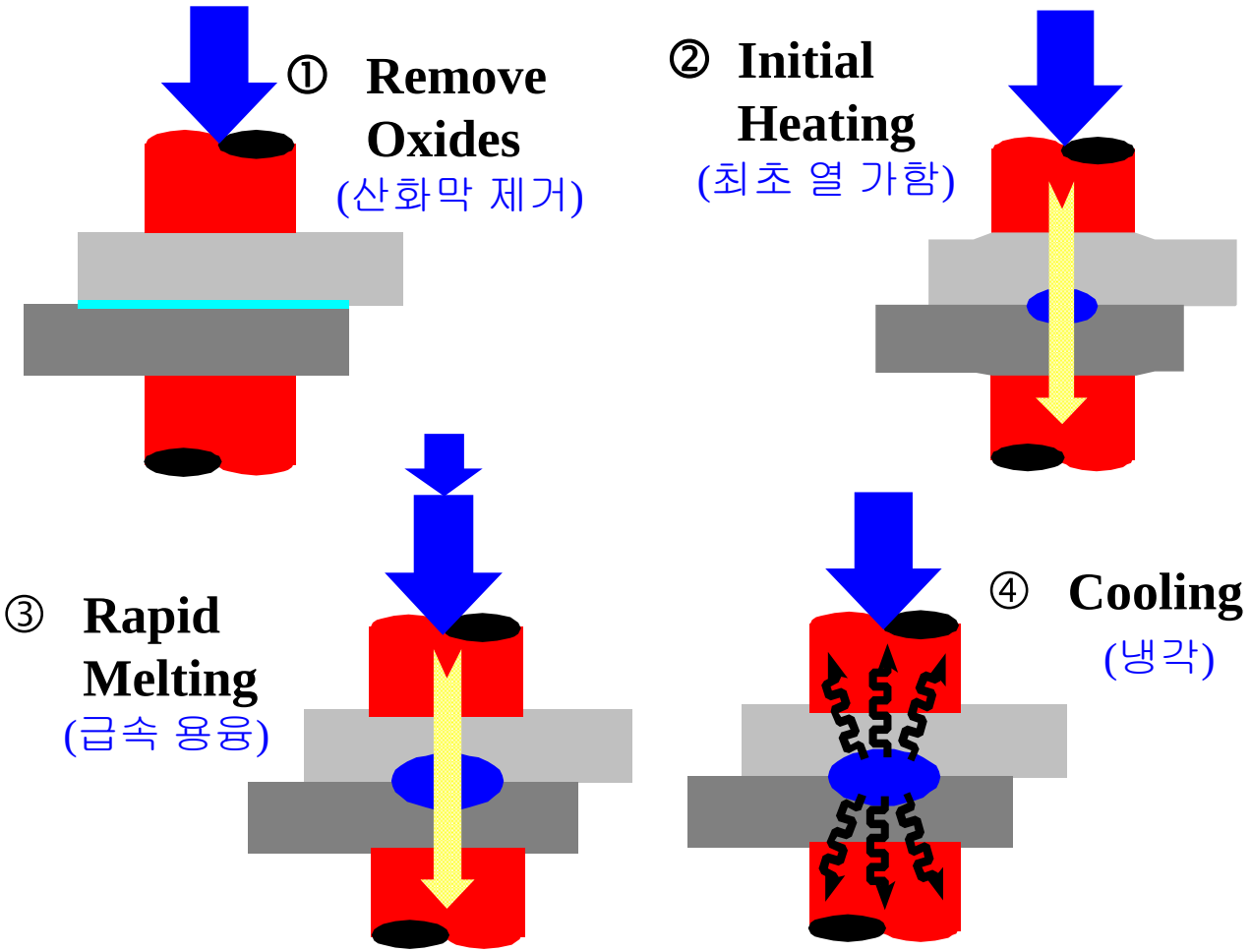
- ☐ Wide variations in weld strength
  (용접 강도 차이가 크게 남)
- ☐ Excessive part deformation
  (과도한 부품 변형)
- ☐ Weld splash
  (스파크 발생)
- ☐ Reduced electrode life
  (전극 수명 단축)
- ☐ Inconsistent weld heat
  (불규칙한 용접 열 발생)

Electrode Force vs. Time Before and After EZ-Air:





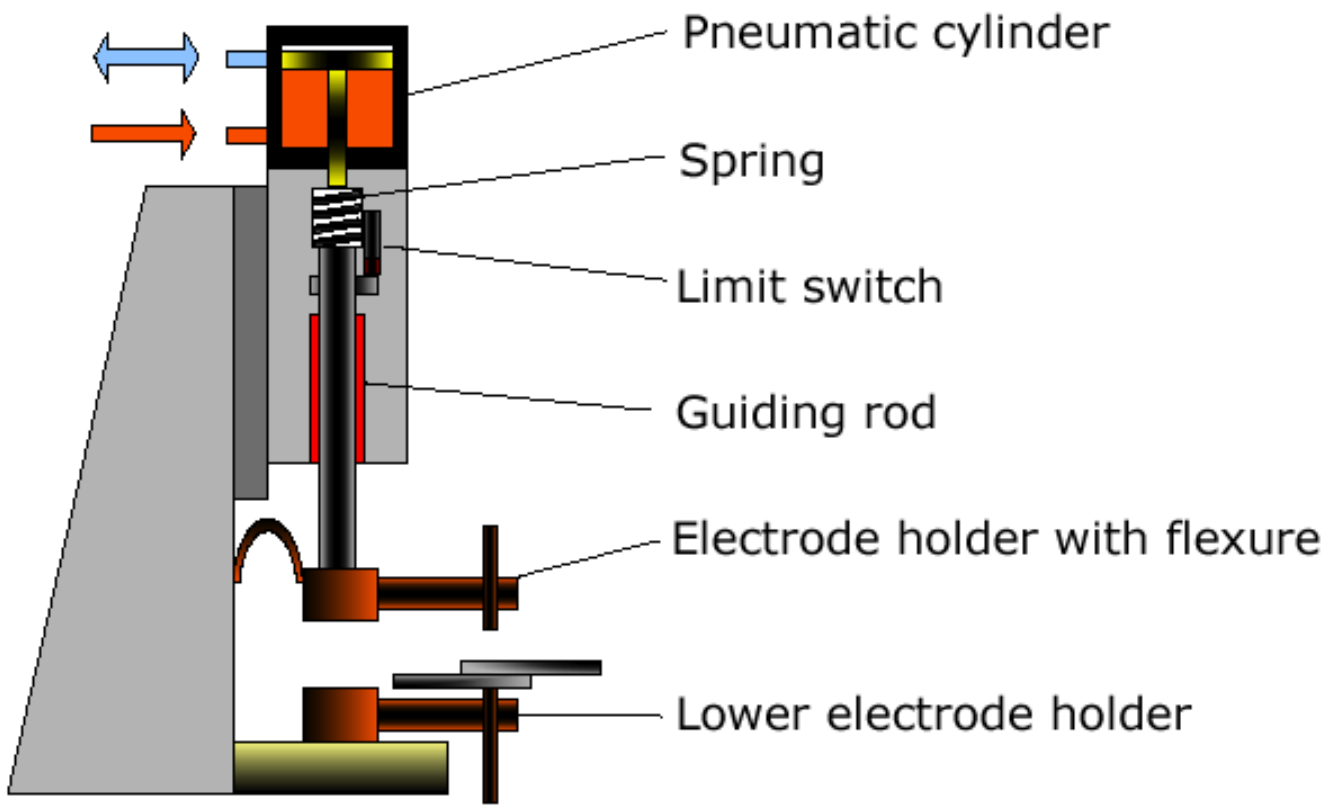
Weld Head Actions (용접 헤드의 동작 순서)



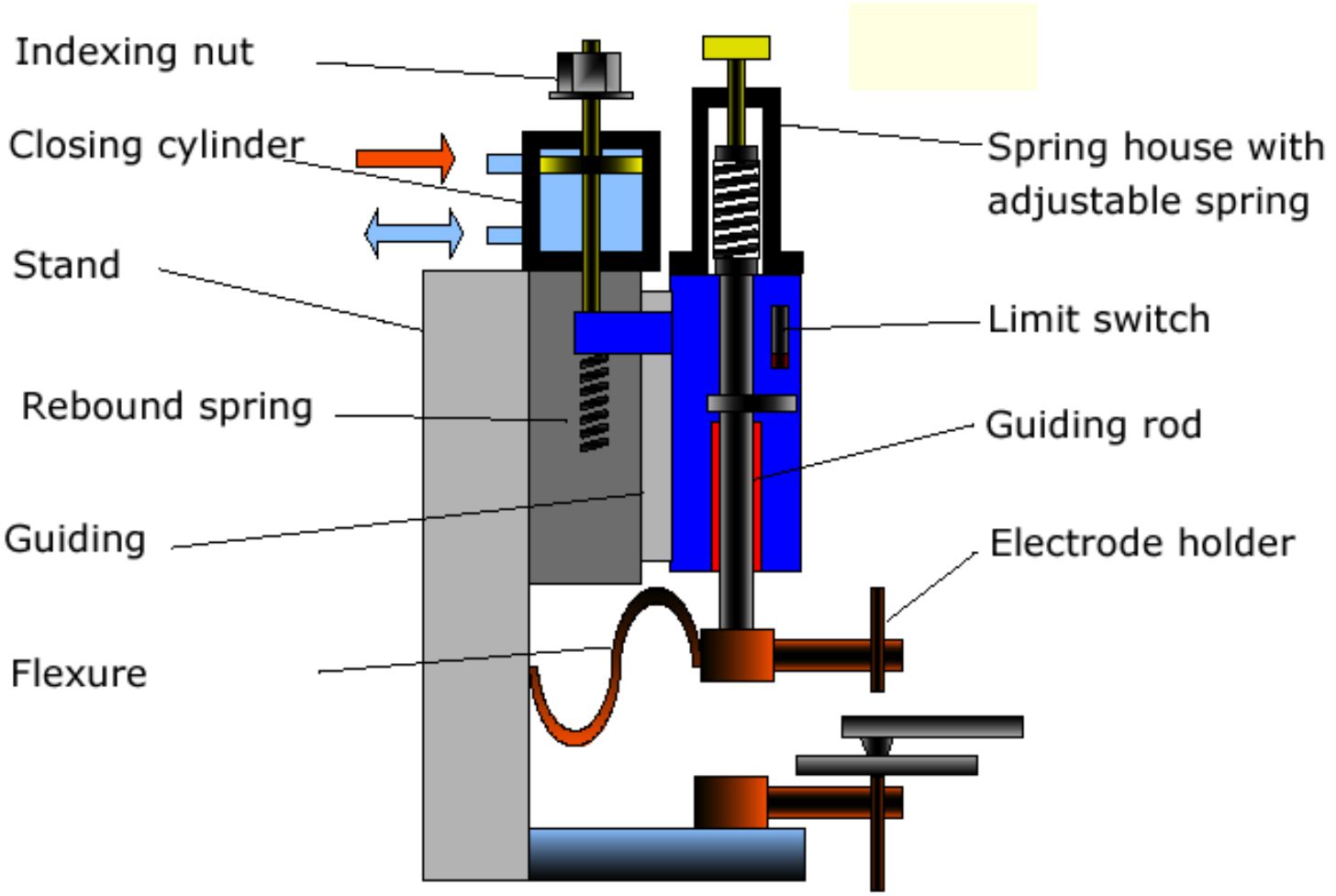
Weld Head Actuation Methods(용접헤드 작동방법)

- Manual (수동식)
  - ➔Foot Pedal & Coil Spring
    (발 페달 & 코일 스프링)
- Pneumatic (공압식)
  - ➔Direct Air (직접적인 공기압)
  - ➔Coil Spring (코일 스프링)
- Electro Magnetic (전자기식)

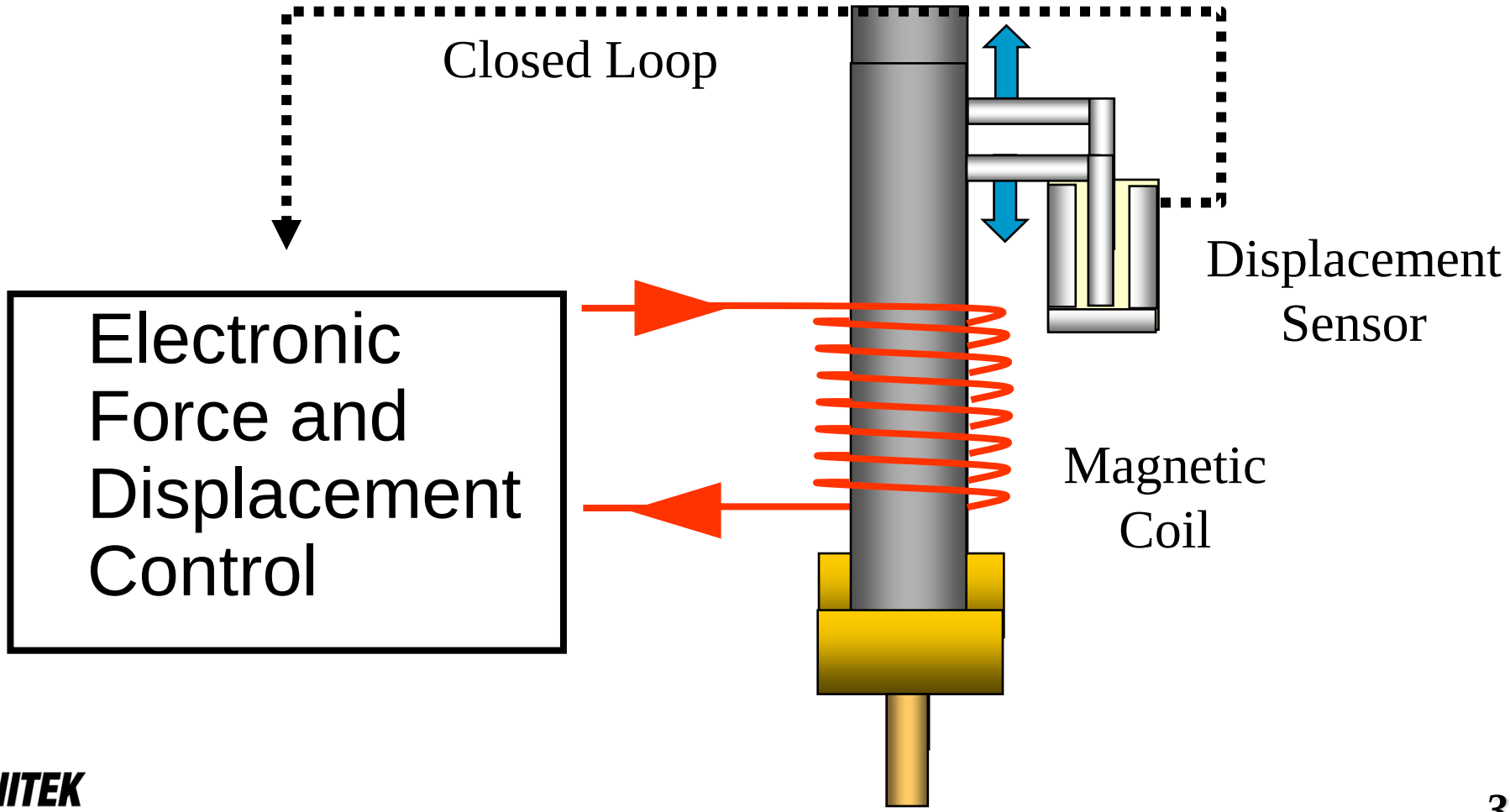
Direct Pneumatic Drive



Spring actuated head



Electro-magnetic, Linear Actuated



Comparison(용접헤드 비교)

● **Best**

◒ **Marginal**

○ **Worst**

	Repeatability	Minimum Over-Force	Minimum Impact Force	Max Follow-up Ability	Minimum Weld Splash	Max Weld Speed	Lowest Equipment Cost
Linear Magnetic Actuator	●	●	●	●	●	●	○
Coil Spring	◒	○	○	◒	◒	◒	●
Direct Air Drive	○	◒	◒	○	○	○	●

Ideal Weld Head (이상적인 용접 헤드)

- No Impact Force (충격 하중 없어야 함)
- No Over-force (과다한 하중 없어야 함)
- Force Fired Weld Current (하중 전달 과 동시에 용접 전류 전달)
- Infinite Weld Current Capacity (무한한 용접 전류 용량)
- Perfect Electrode Follow-up (완벽한 전극 동작 수행)
- Force and Displacement Monitoring (하중의 이동 확인 가능)

Controller

용접 파워서플라이의
종류 및 특징

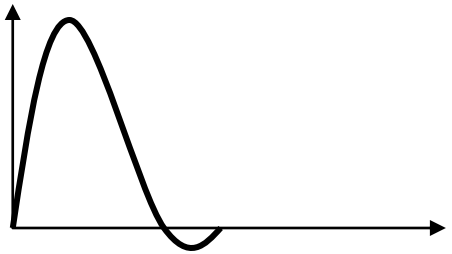
Controller

1. Power Supplies (전원발생장치)
2. Closed Loop & Feedback
   (닫힌 회로 & 피드백)
3. Process Tool (APC, Energy Limit, etc.)

Technologies:

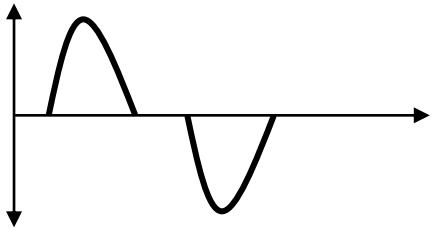
1.1. Capacitor Discharge (CD)

(캐패시터 방전)



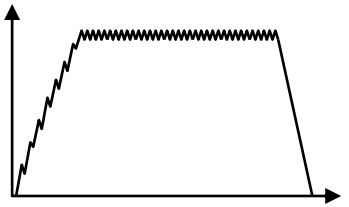
1.2. Direct Energy (A.C.)

(교류 에너지)



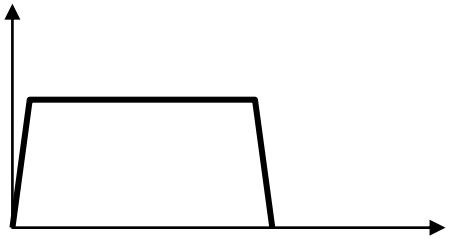
1.3. High Frequency Inverter (HF)

(고주파 인터버)



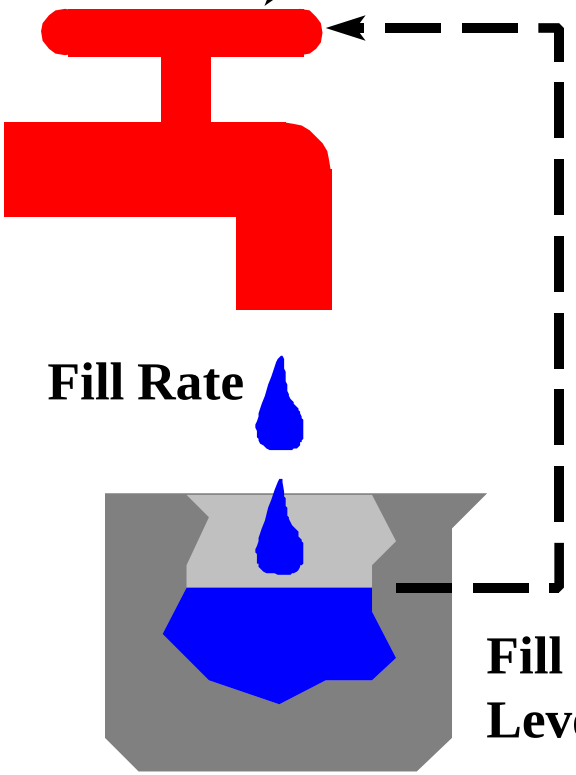
1.4. Linear / Transistorized DC

(선형 / 트랜지스터 DC)

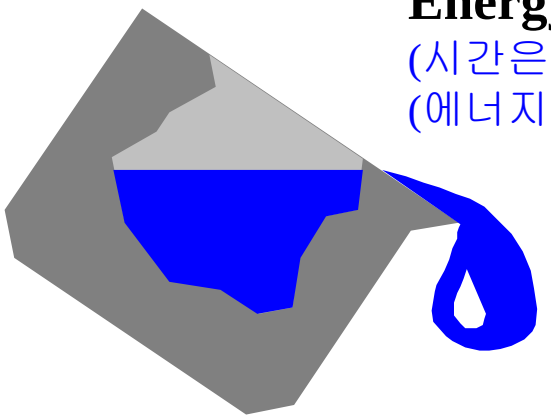


1.1.Capacitive Discharge (CD) (캐패서터 방전)

On/Off Valve = Energy Control (에너지 제어)



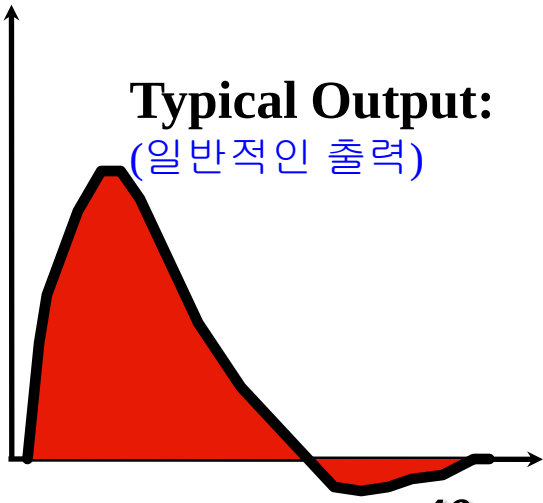
Bucket Size =
Total Energy
(통의 크기 = 총 에너지)



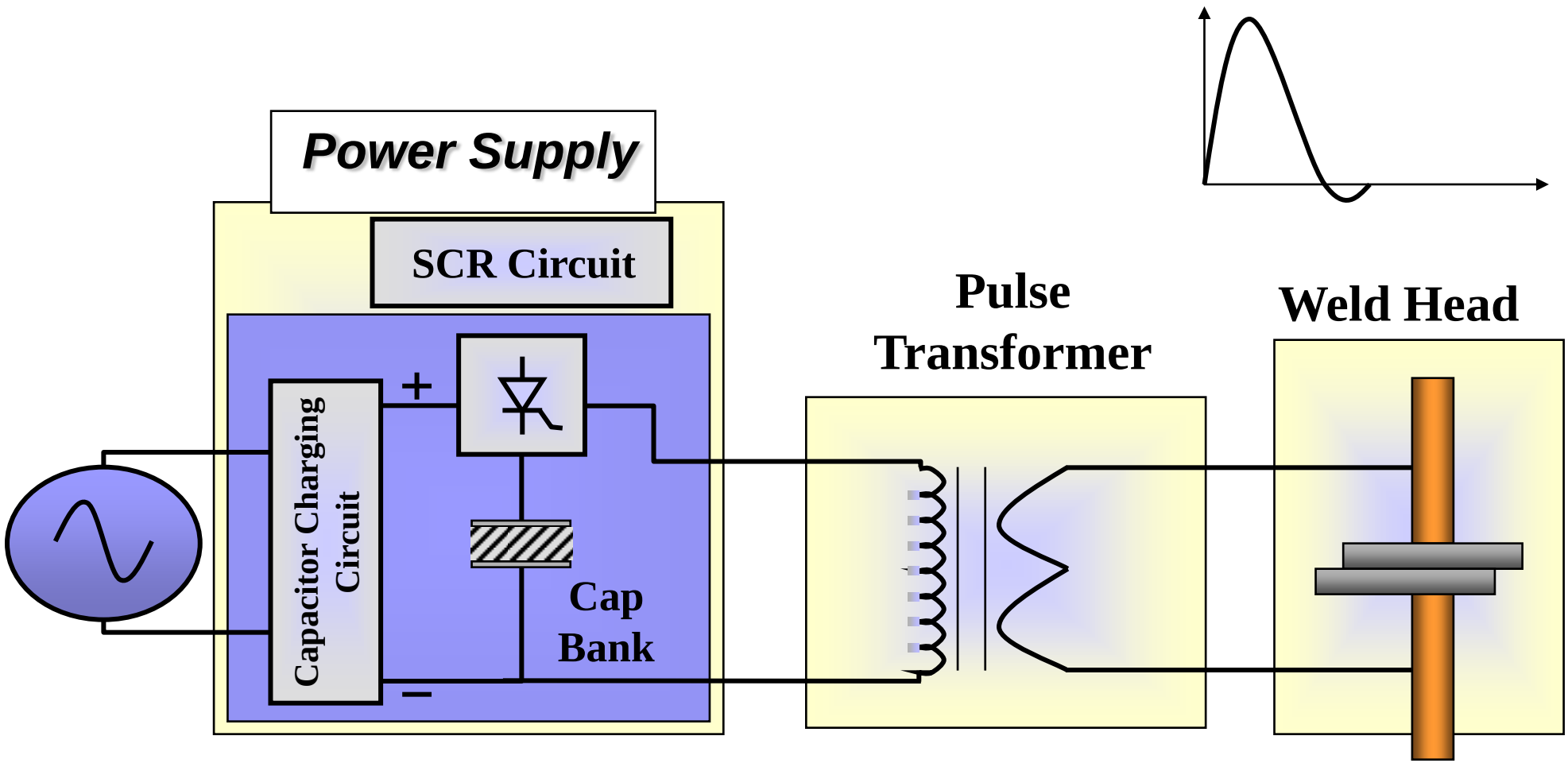
Dumping Time =
Pulse Width
(방전 시간 = 펄스 폭)

Time Control in Pulse Widths
Energy Control in Watt-Sec
(시간은 펄스 폭으로 조정)
(에너지는 Watt-sec로 조정)

Typical Output:
(일반적인 출력)



1.1. Capacitor Discharge (CD) 회로도



1.1.Capacitive Discharge (CD)

Welding Characteristics (용접 특성)

- Stores energy prior to weld (충전된 에너지를 용접에 이용)
- Time control uses different fixed pulse widths
  (시간 제어는 이미 지정된 펄스 폭 이용)
- Weld energy is independent of line voltage changes
  (용접 에너지는 입력(상용) 전압의 변화에 영향을 받지 않는다)

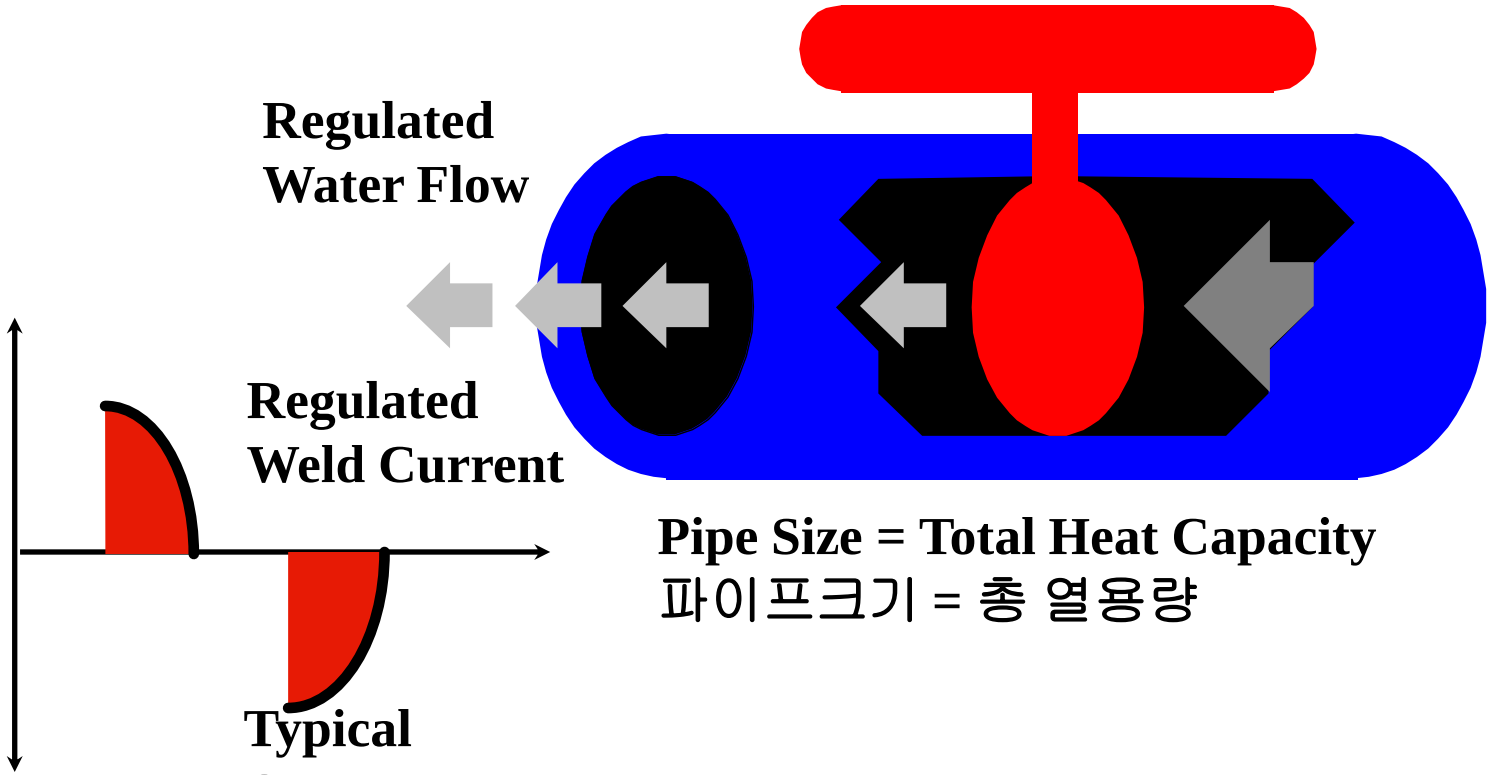
- Fast rise time with high peak current.

(최대치 전류값이 크면 상승시간이 빠르다)

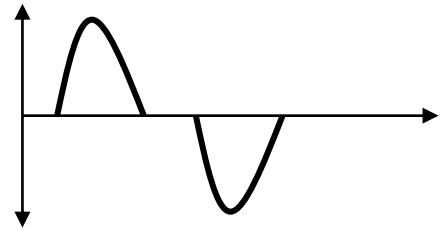
- Good for welding conductive parts (전도성 부품의 용접에 적합)

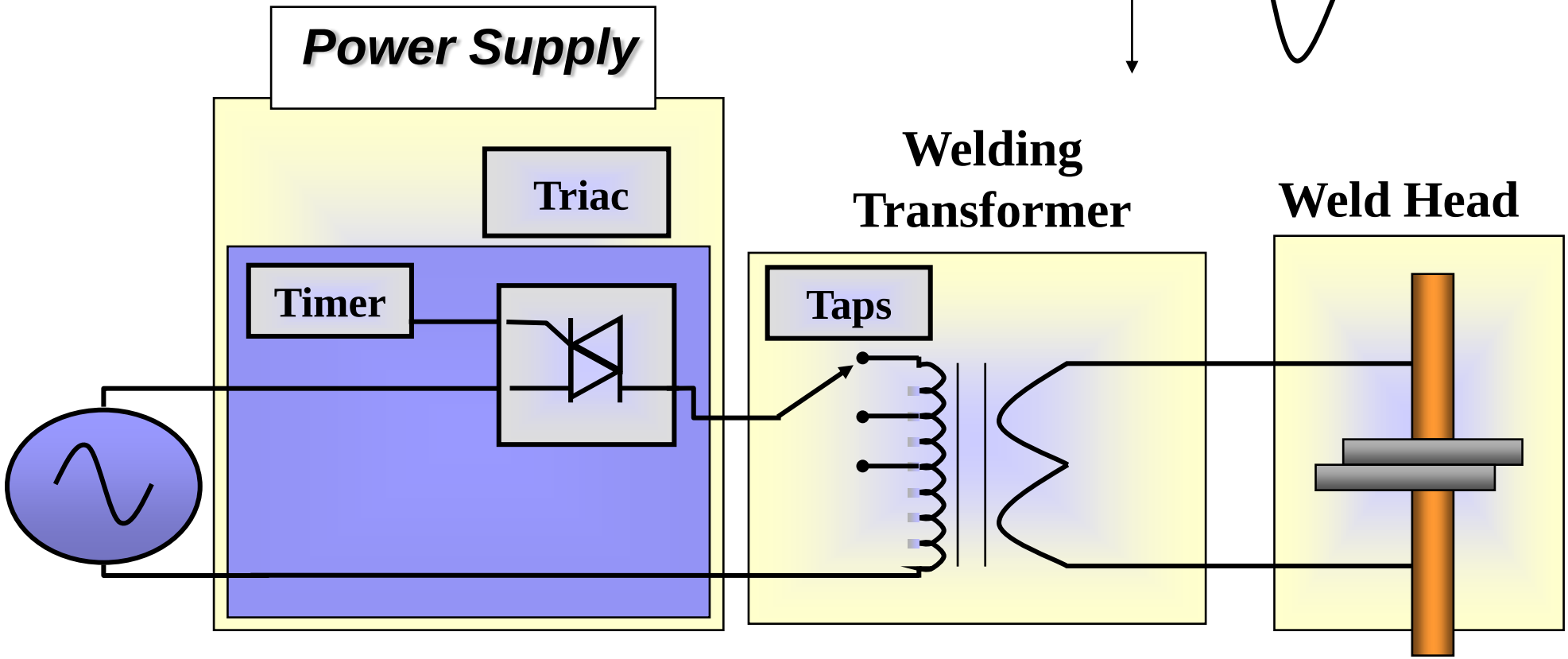
1.2. Direct Energy (AC)

ON/OFF Valve = Time Control and Flow Control



1.2. Direct Energy (AC) 회로도





1.2.Direct Energy (AC)

Welding Characteristics (용접 특성)

- ☐ Immediate weld energy use (즉각적인 용접 에너지 사용)
- ☐ Time control uses line voltage cycles

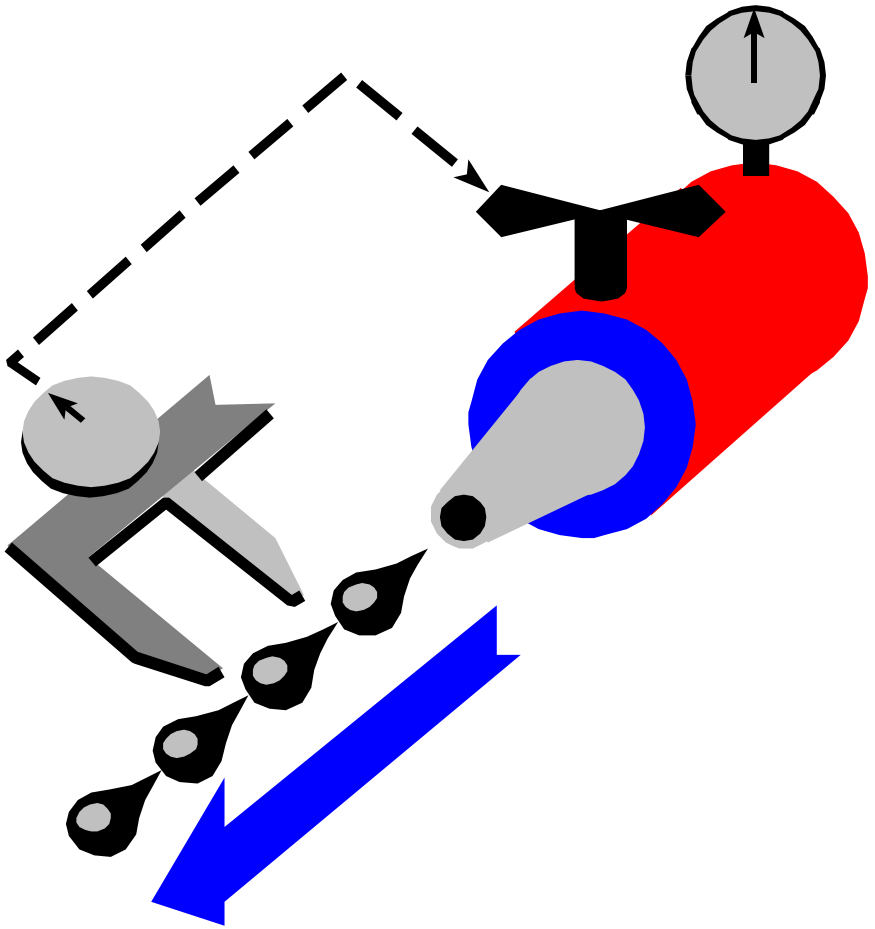
  (시간조정은 입력(상용) 전압의 주기를 이용)
- ☐ Weld energy can be sensitive to line voltage changes

  (용접 에너지는 입력(상용) 전압의 변화에 따라 변할 수 있다)

General purpose welder with high energy output.

(고출력을 낼 수 있는 일반적인 용접기에 사용)

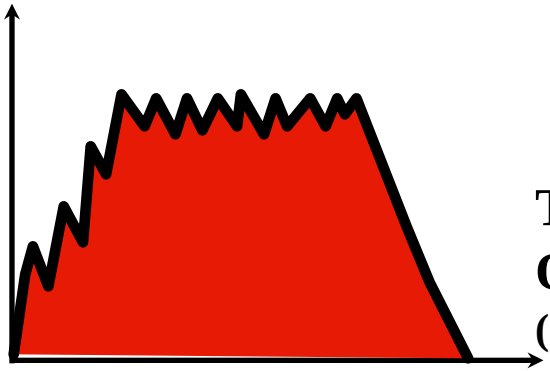
1.3.High Frequency Inverter (HFDC)



Constant Voltage (CV)
= Water Pressure

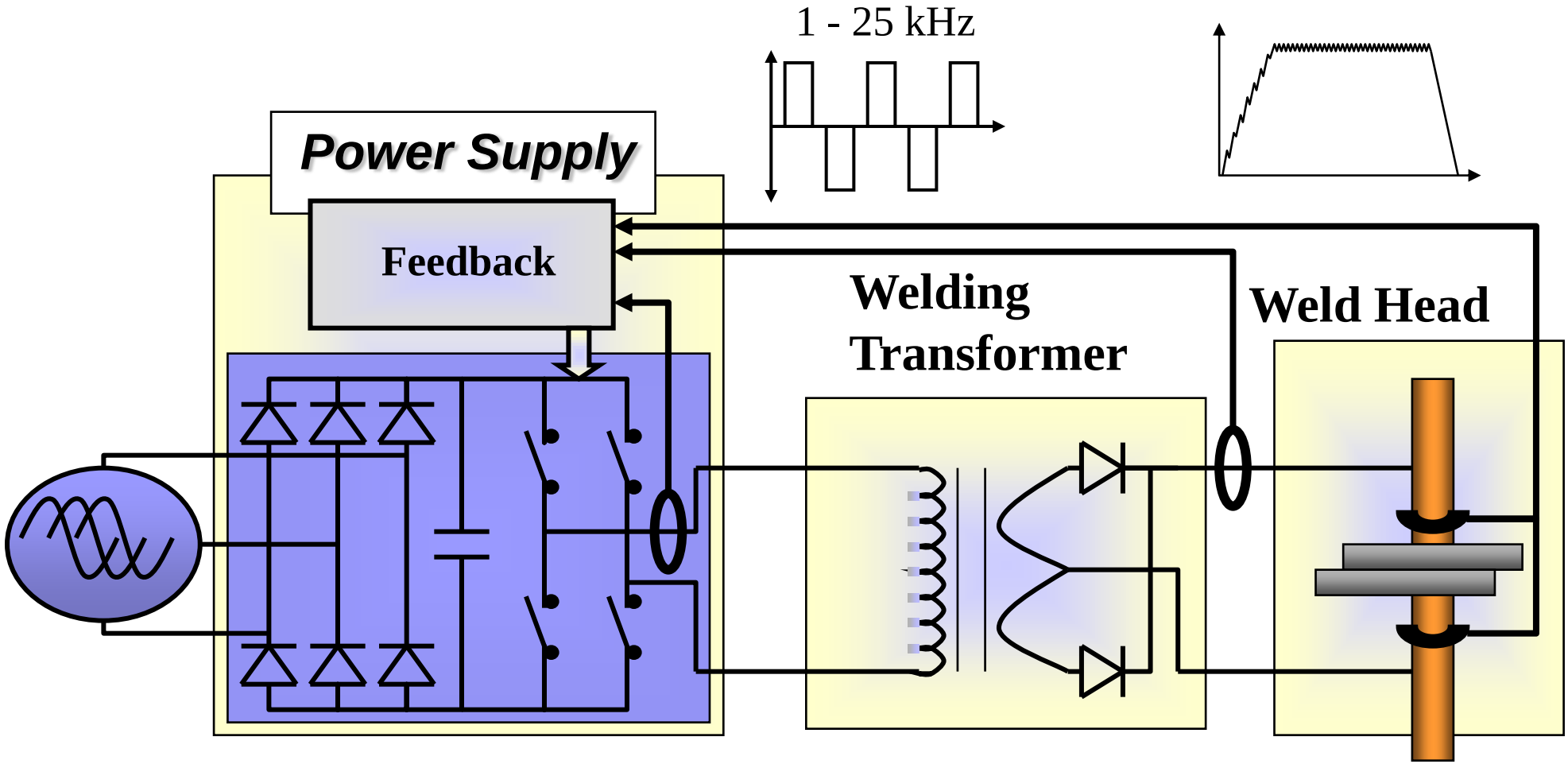
Constant Current (CI)
= Water Flow

Constant Power (CP)
CP = CV x CI
= Nozzle Thrust



Typical Output
(전형적인 출력)

1.3. High Frequency Inverter 회로도

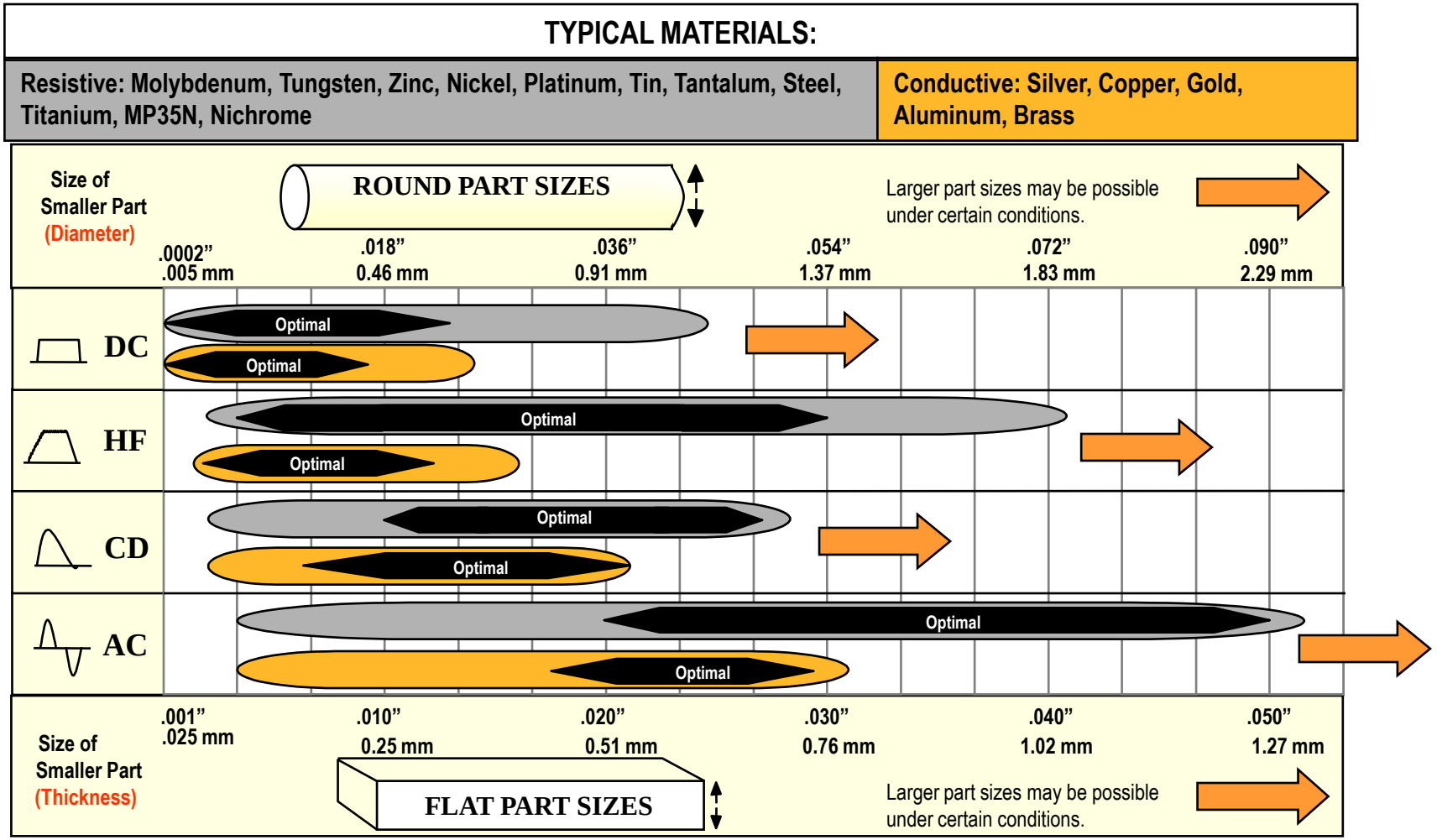


1.3.High Frequency Inverter (고주파 Inverter)

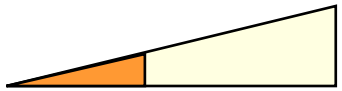
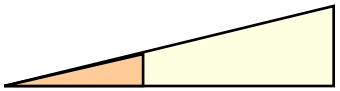
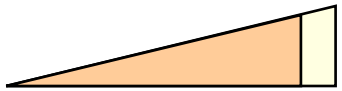
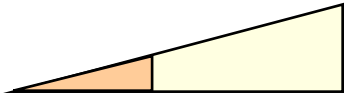
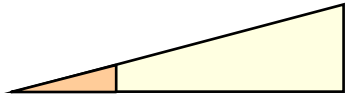
Advanced Functions (진보된 기능들):

- Multiple Control Modes: Current, Voltage, or Power
  (다기능 모드 : 전류, 전압 or 전원)
- Time control in 0.1 millisecond increments
  (0.1 밀리 초 마다 시간 조정)
- Close Loop & Feedback Mode (닫힌 루프 & 피드백 모드)
- Precision Time Control (정밀한 시간 조절)
- Accurate Pulse Shaping (정확한 펄스 형성)

Capability vs. Optimal Range (성능 vs. 최적화 범위)

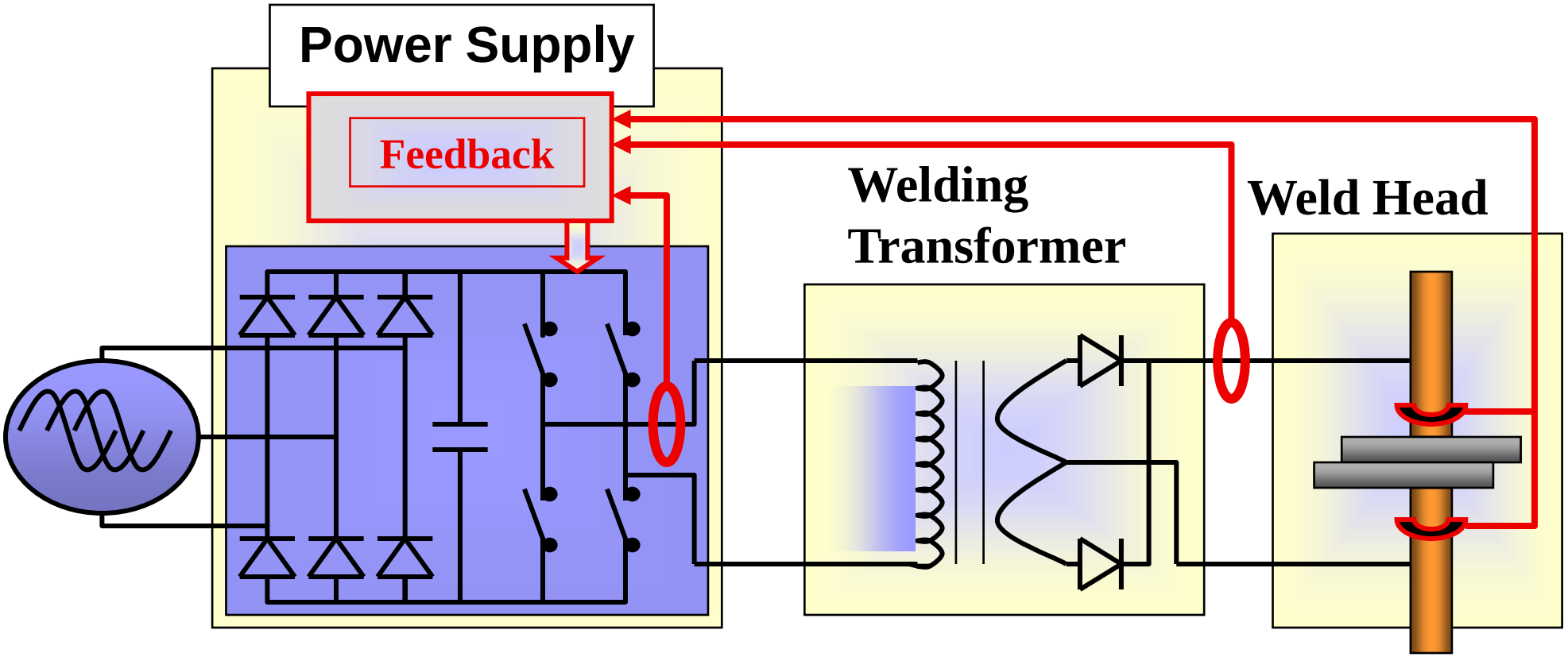


Specification Comparison (사양 비교표)

	Closed Loop:		Open Loop:	
	DC	HF	CD	AC
Input Power	115V; 230V Single Phase	240V; 400V; 480V Three Phase	115V; 230V Single Phase	115V; 230V; 460V Single Phase
Output Range	5-4000 Amps	50-4000 Amps	Up to 875 WS	Up to 16 KVA
Feedback Modes	I, V, & P	I, V, & P	N/A (Open Loop)	N/A (Open Loop)
Feedback Rate	>10 micro-sec	40-250 micro-sec	N/A (Open Loop)	N/A (Open Loop)
Weld Monitoring	Built-in I, V, & P	Built-in & Sentry	Sentry Option	Sentry Option
Time Control in:	.01 msec steps	0.1 msec steps	Pulse Widths	Line Cycles
Repetition Rate				
Equipment Cost				
Application and Use Notes	Fine energy control, smooth waveform. Best choice for welding fine wires & foils.	Best automation supply. Extends electrode life. Welds wide range of applications.	Fast rise time with high peak current. Good for welding conductive parts.	General purpose control with high energy output. Longer weld times useful for brazing.

2. Closed Loop & Feedback

Controller

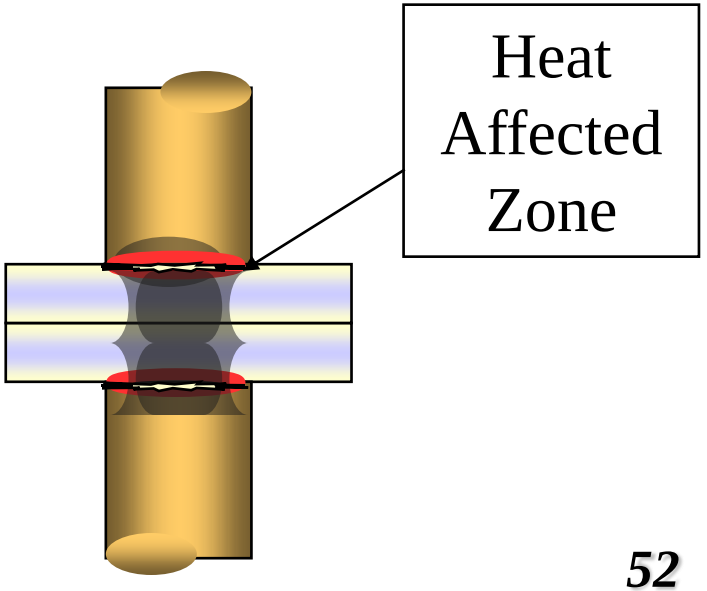


2.1.Controlled Heating Rate (Upslope)

- If too much energy is applied before the electrodes have a chance to seat properly, energy will be wasted at electrode to part contact area. (전극이 알맞게 안착 되기 전에 너무 많은 에너지가 공급된다면 에너지는 전극과 부품간 접촉 면에서 소모(스파크 발생) 될 것이다.)

- Without controlled upslope can result in (Upslope 없을때 나타나는 현상):

- Expulsion (변형)
- Electrode Sticking
  (전극이 용접시료에 붙는다)
- Excessive Marking
  (과도한 용접 자국)
- Weak Welds (약한 용접)



2.2 Feedback Modes

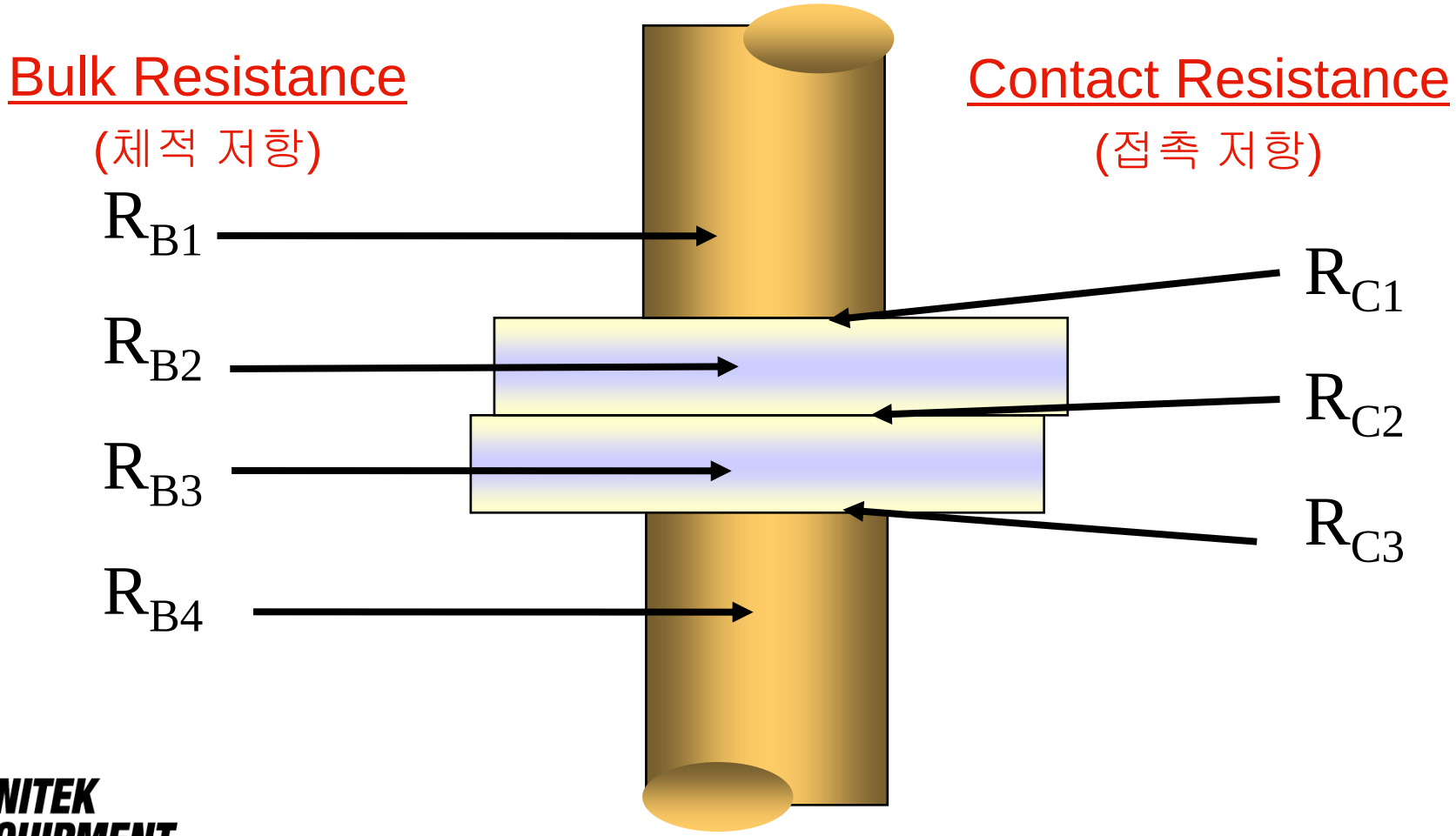
1) **Constant Current** **Weld Heat = (I^2R) x t x K**
2) **Constant Voltage** **= (V^2/R) x t x K**
3) **Constant Power** **= (I x V) x t x K**

□ Selection based (선정 근거)

- R (resistance) and K (thermal factor) during welding
  (용접중에 저항과 열 상수값 변화 유무)
- Part and process challenge (용접 시료와 공정 문제)

2. Closed Loop & Feedback

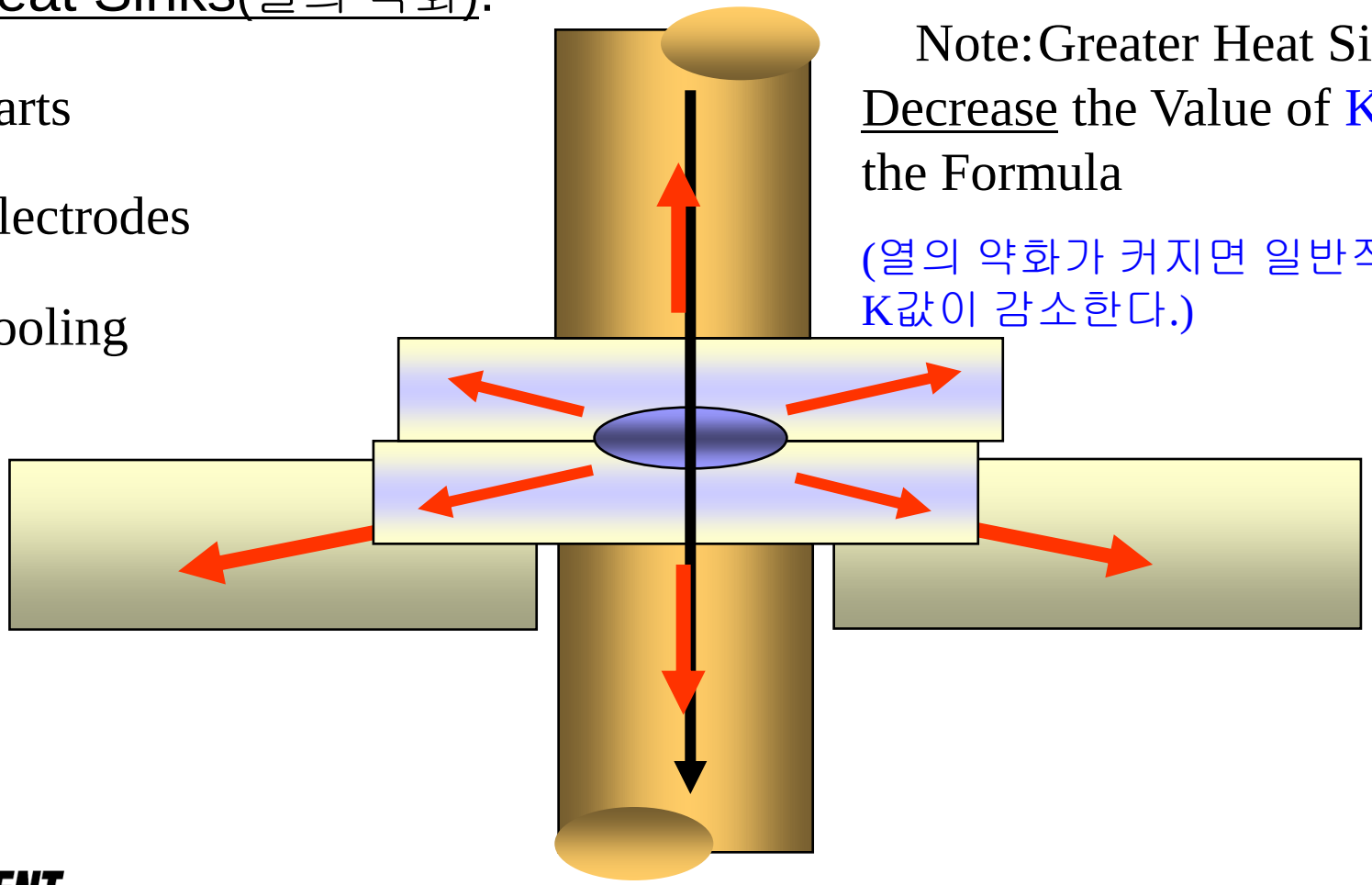
Total Work Piece Resistance (R) =
Bulk + Contact Resistance (체적 + 접촉 저항)



Thermal Factor (K) (열적 상수)

Heat Sinks(열의 약화):

- Parts
- Electrodes
- Tooling



Note: Greater Heat Sinks Decrease the Value of K in the Formula

(열의 약화가 커지면 일반적으로 K값이 감소한다.)

2. Closed Loop & Feedback **Controller**

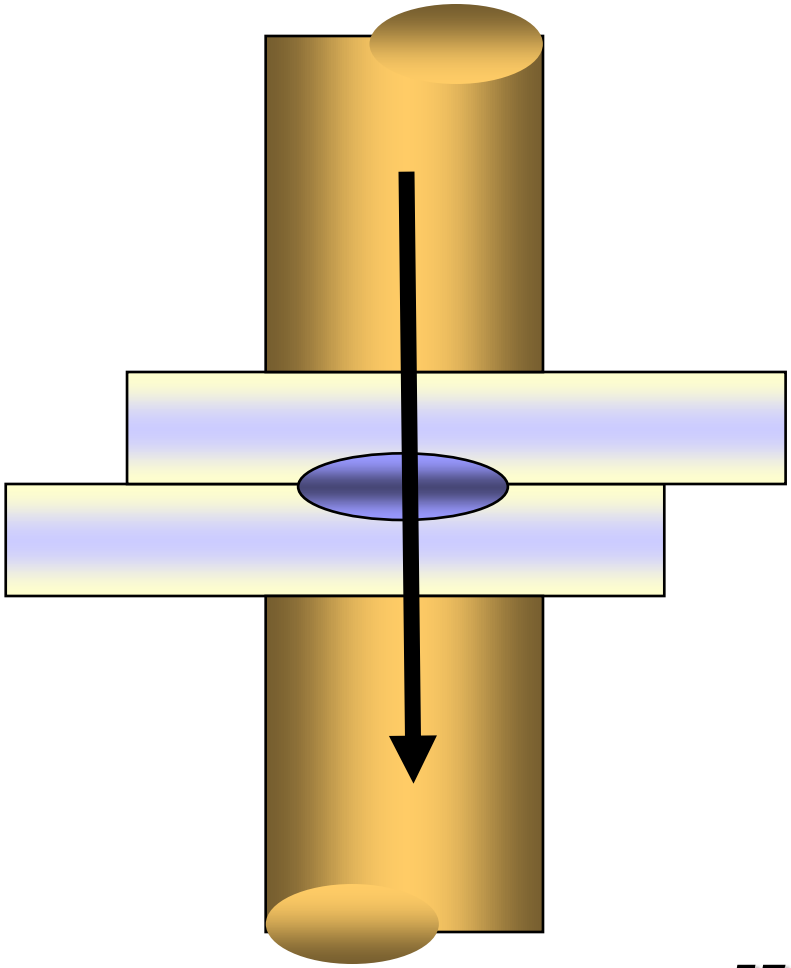
Feedback Mode	R & K	Part Challenges	Process Challenges
Constant Current	Both consistent	Flat Parts Thickness Inconsistencies Wireweld.	
Constant Voltage	Both change	Non flat Projections Varying gap	Part Misplacement Varying Overlap Inconsistent Force Mushroomed Electrodes
Constant Power	R: change K: Consistent	Surface Roughness Plating Inconsistencies Oxidized Parts Contamination	Oxidized Electrodes Automated Systems

Constant Current

$$Q = (I^2R) \times t - K$$

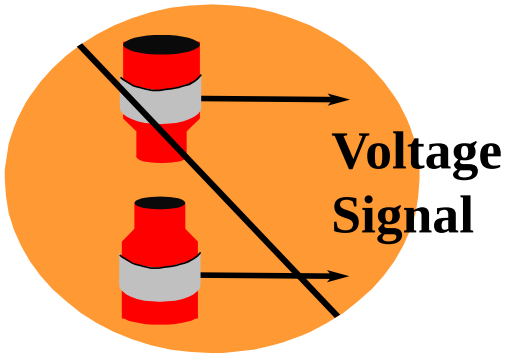
- R and K are controlled and consistent (R 과 K 값 일정)
- Flat parts where the part-to-part and electrode-to-part contact is consistent (평평한 용접시료 및 전극)
- Force control is critical

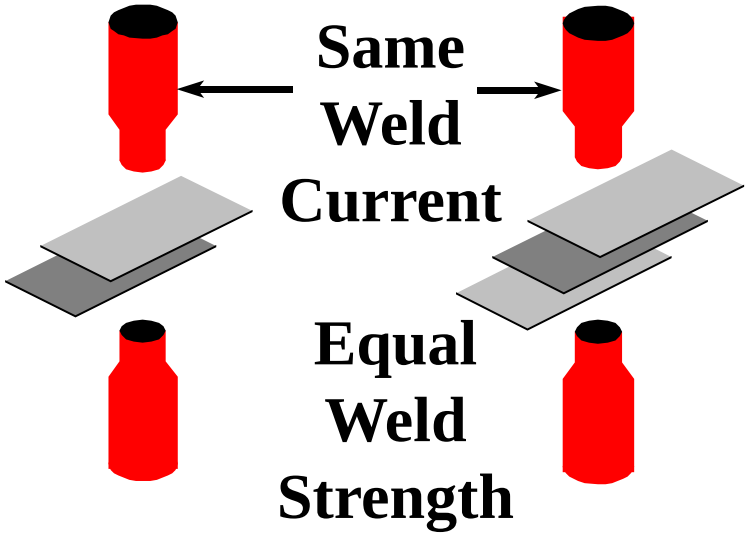
  (용접 가압력이 매우 중요)



Constant Current Applications (정전류 응용)

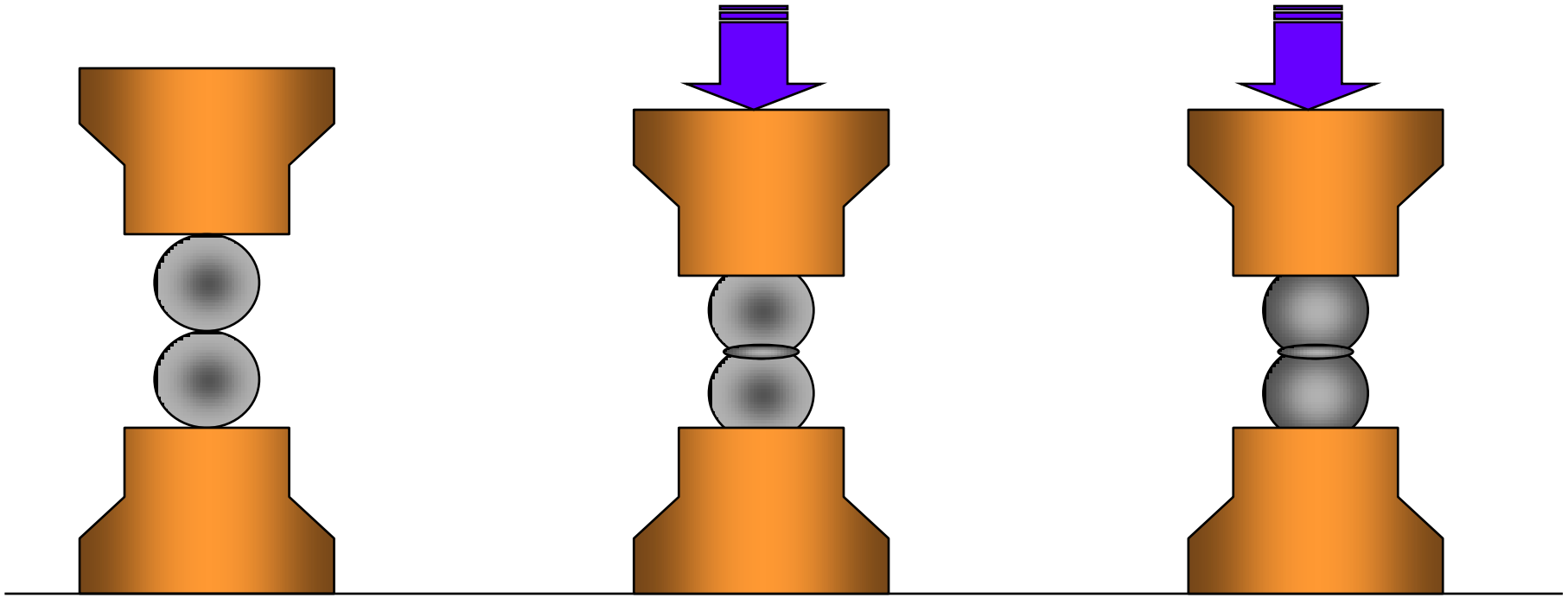
- Good for 70 - 75% of all applications! (70~75% application에서 사용)
- Small variations in thickness (두께의 변화가 적다)
- Part-to-part contact or electrode-to-part contact is consistent
  (시료와 시료 접촉 또는 전극과 시료 접촉이 서로 일정)
- Simpler to set up and install (설치및 용접 조건의 설정이 간단)





Constant Current Applications : Wire Weld

Three Stages of Heat Generation (3단계 열발생):



Beginning of Weld High Contact Resistance

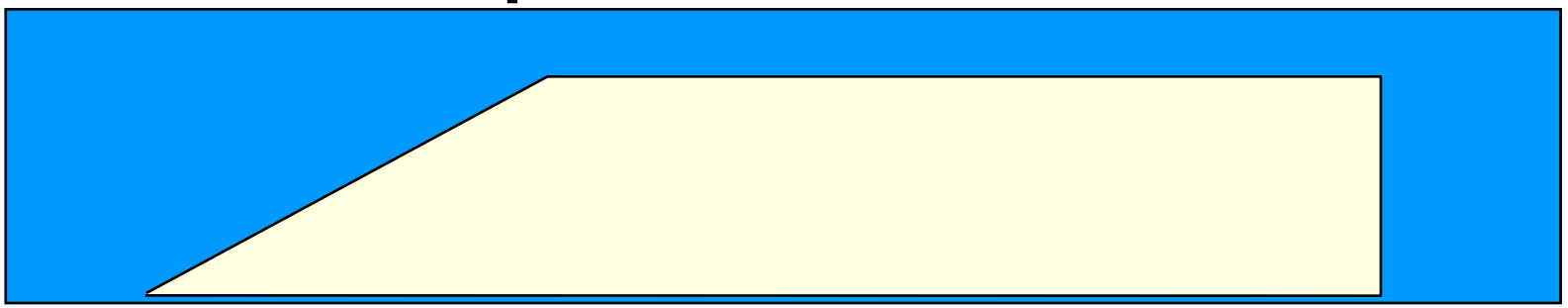
Wires Deform Reduced Contact Resistance

Parts Melt Severe Resistance Drop

Constant Current Applications : Wire Weld

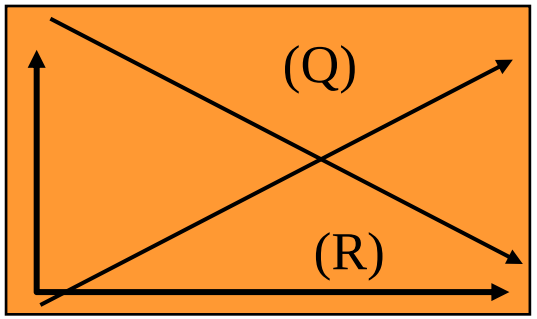
Use Constant Current with Upslope:

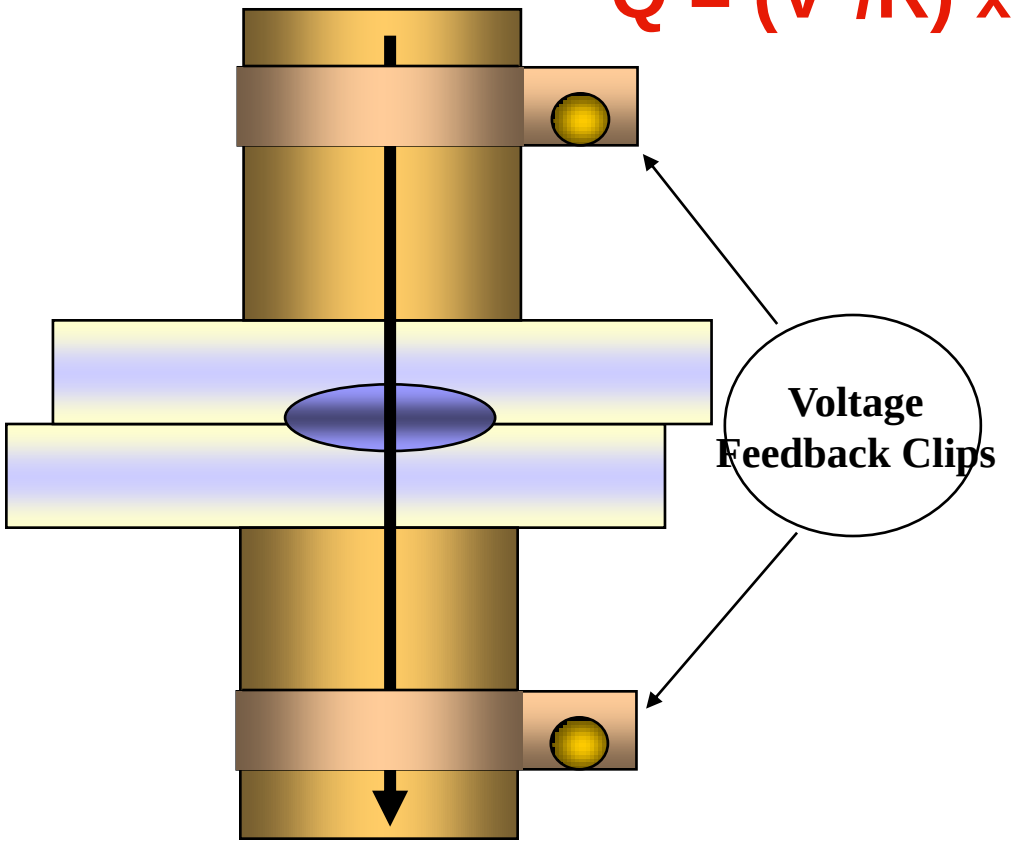
Upslope addresses the high contact resistance in the beginning of the weld.
Constant Current addresses the severe resistance drop in the end of the weld.



Constant Voltage

$$Q = (V^2/R) \times t - K$$

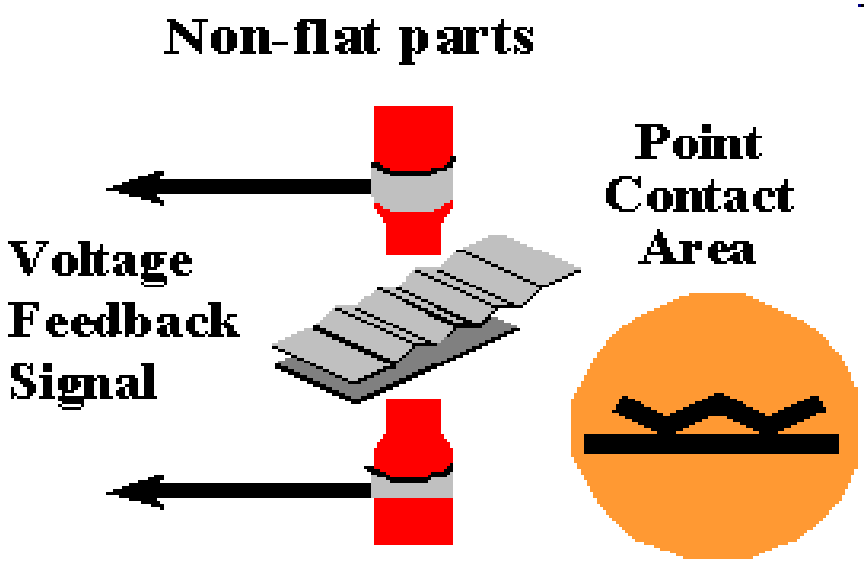


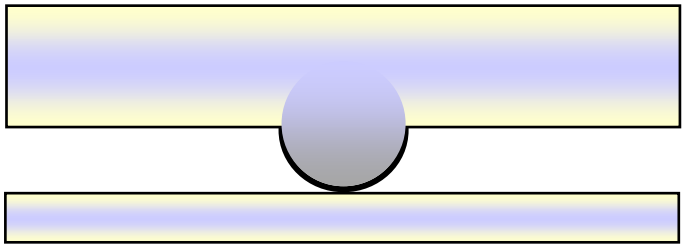


- R and K both increase or decrease. (R 과 K 둘다 변화)
- non-flat parts (projections)
- to compensate for part misplacement and force problems. (용접시료 오배치와 가압력 문제를 보상하는데)

Constant Voltage Applications (정전압 응용)

- Prevent blow-out when welding parts with small contact areas (large R)
  (작은 접촉 면적(높은저항) 으로 부품을 용접할 때 충격을 예방)
- Compensate for inconsistencies in part-to-part and electrode-to-part contact area
  (부품과 부품간 그리고 전극과 부품간 접촉 면적에서 불일치한 점을 보완)



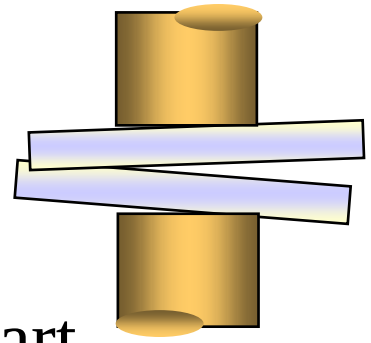


Projections

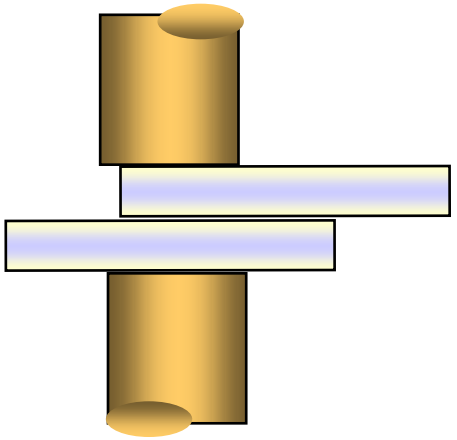
Constant Voltage Applications

Both resistance (R) and heat sinking (K) are affected.

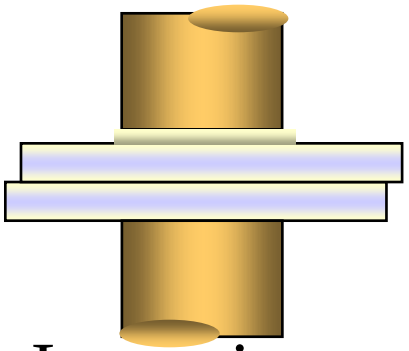
(R 과 K 양쪽 모두 영향을 받는다)



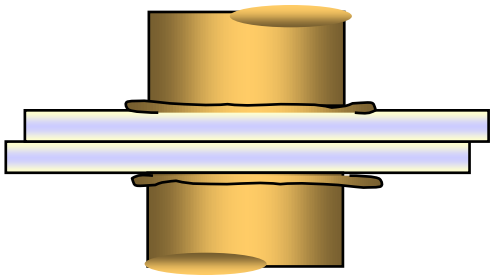
Part Misplacement



Varying Overlap



Inconsistent Force

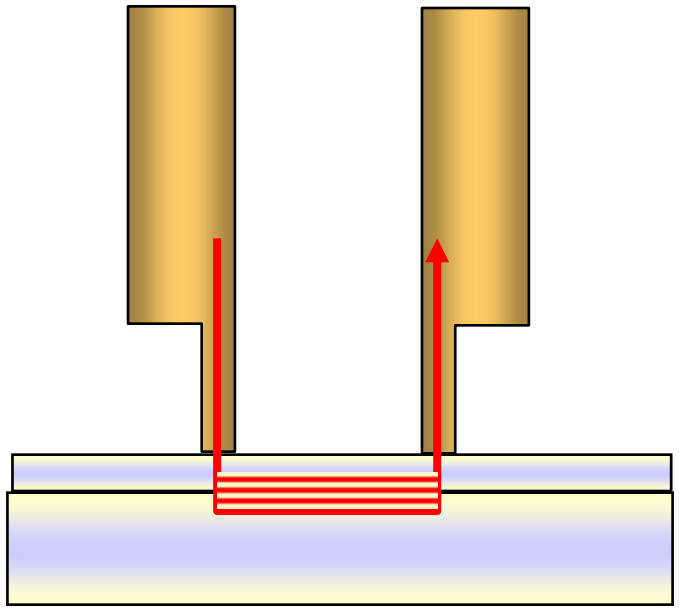


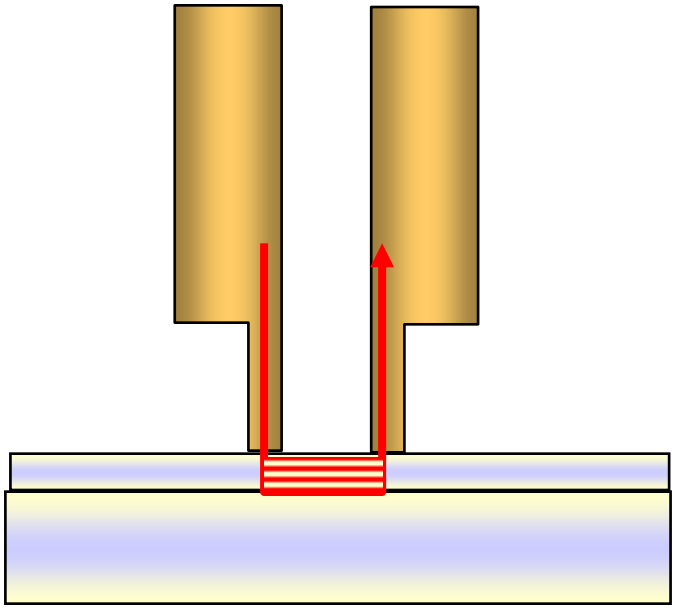
Mushroomed Electrodes

Constant Voltage Applications

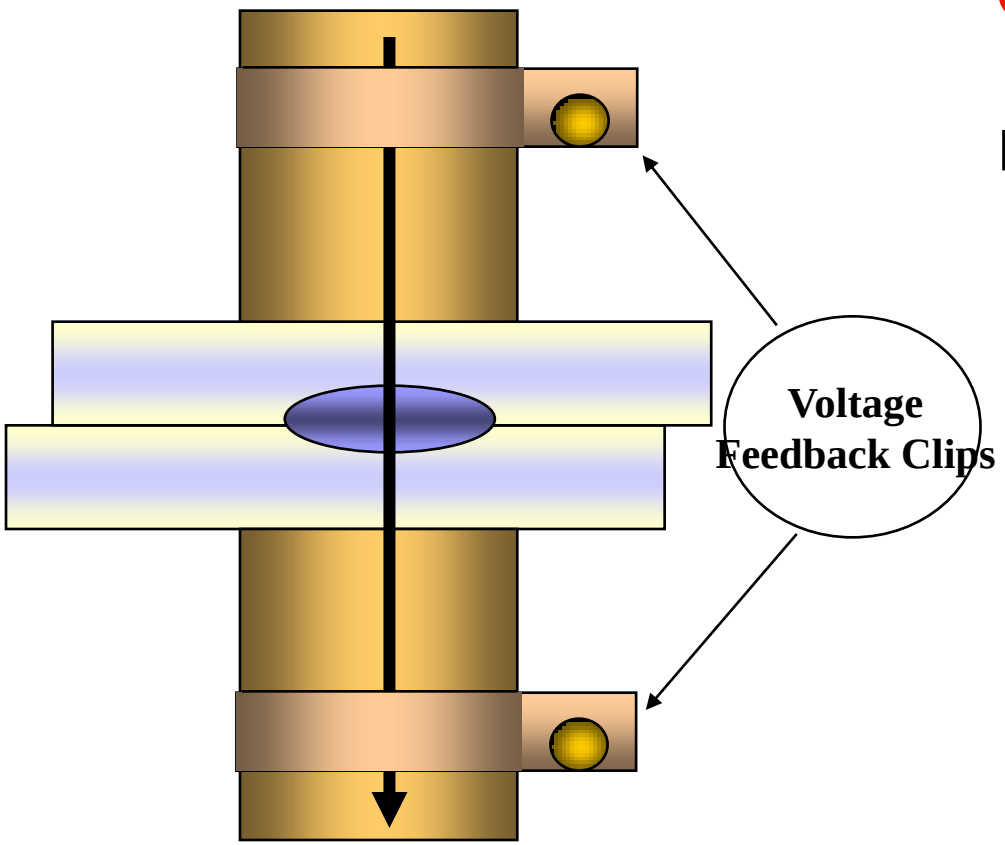
Both (R) and (K) are affected by varying gap.

(R 과 K 양쪽 모두 간격의 변화에 의한 영향을 받는다)





Constant Power



$$Q = (I \times V) \times t - K$$

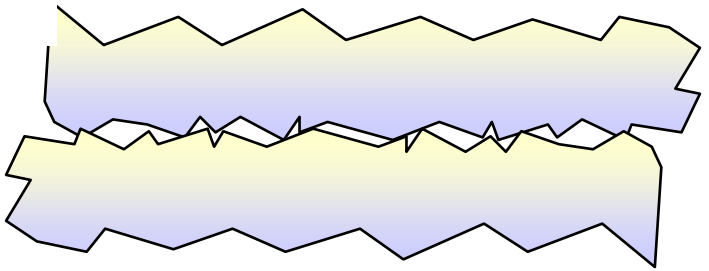
- For applications where R changes from weld to weld, where K (affected by both part placement and force) are consistent.

(R은 변하나 K는 일정할때)

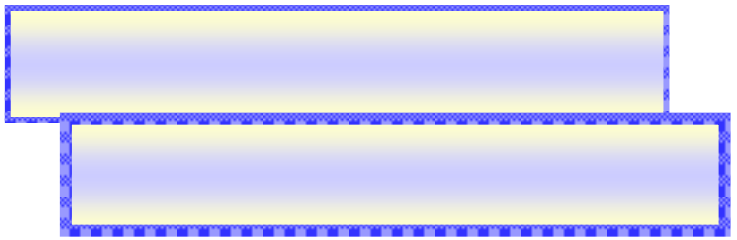
Constant Power Application

Surface conditions affect contact resistance (R), but do not affect heat sinking (K).
(용접 시료의 표면 상태는, R 에는영향을 주나 K에는 영향을 주지 않는다)

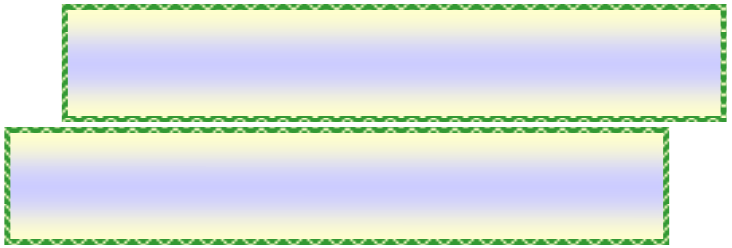
Surface Roughness



Plating Inconsistencies



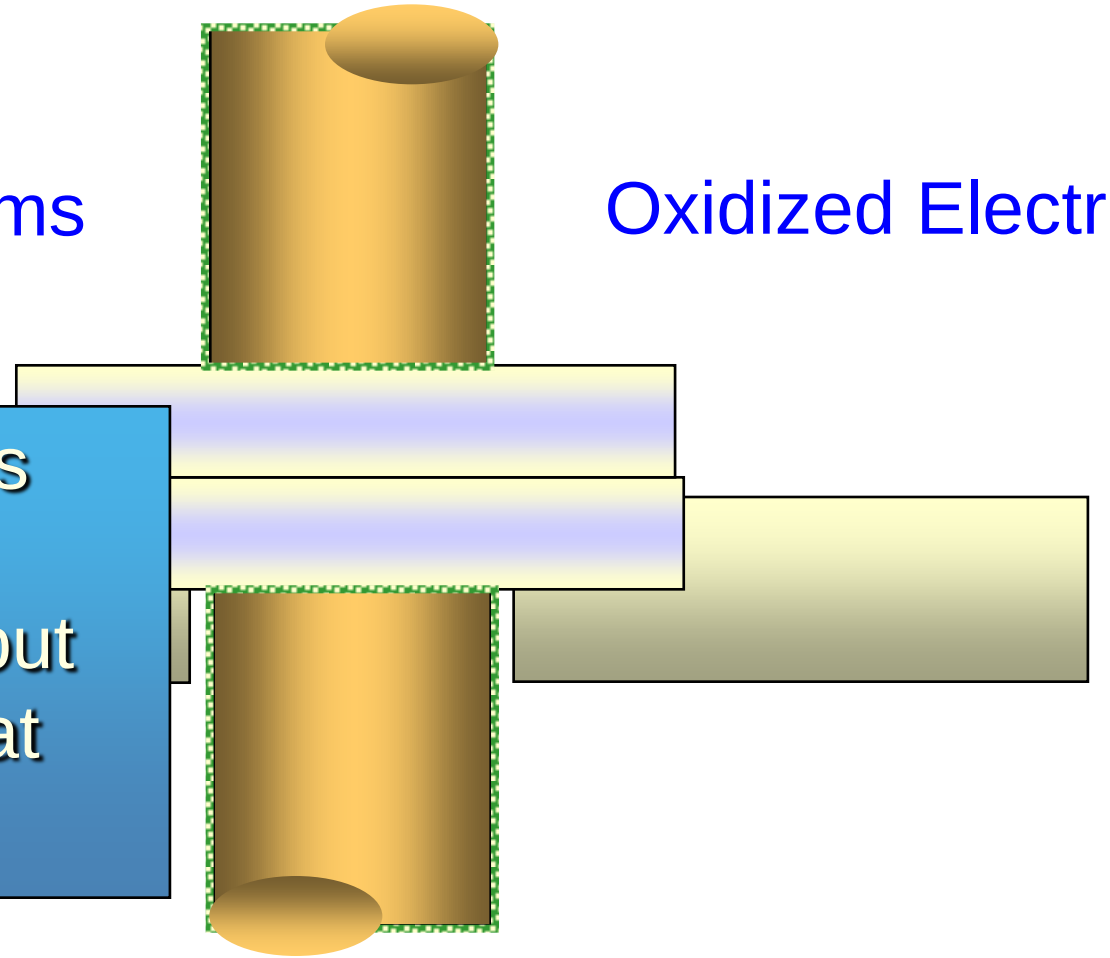
Oxidized Parts



Constant Power Application

Automated Systems

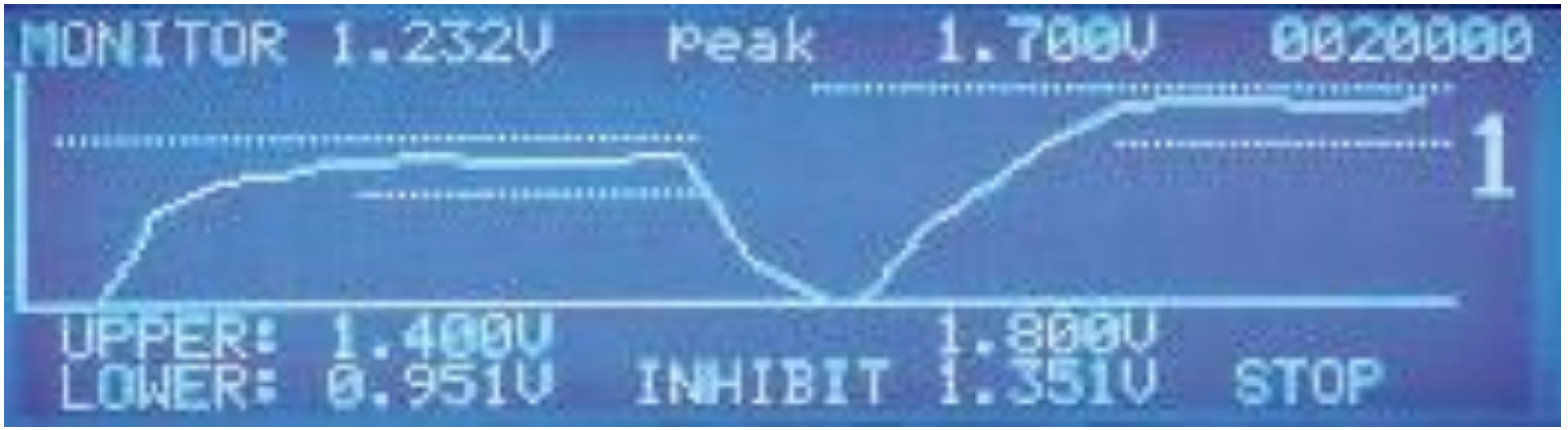
Oxidized Electrodes



These conditions affect contact resistance (R), but do not affect heat sinking (K).

Weld Monitoring

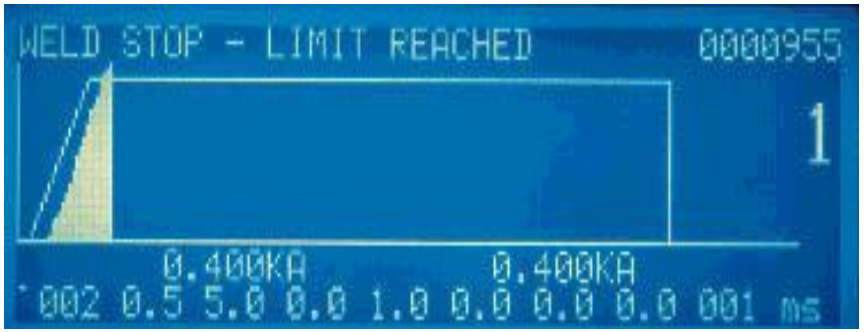
- Graphic waveform traces (그래픽 파형 근거)
- Easy set limits with programmable action (프로그램화 되어 있어 쉬운 설정)
- Simple, dynamic weld information for process understanding and diagnostics (공정 이해와 진단을 위한 간단하고 동적인 용접 정보)



Pre Weld Check

1차 예비 용접시 부품의 불안정한 접촉을 확인하여 용접 중단
-> 부품 및 전극의 손상 예방

Energy Limit



프로그램된 전류, 전압 또는 전력이 설정된 상한값에 도달했을 때 용접은 종료 -> 부품및 전극의 파열 예방

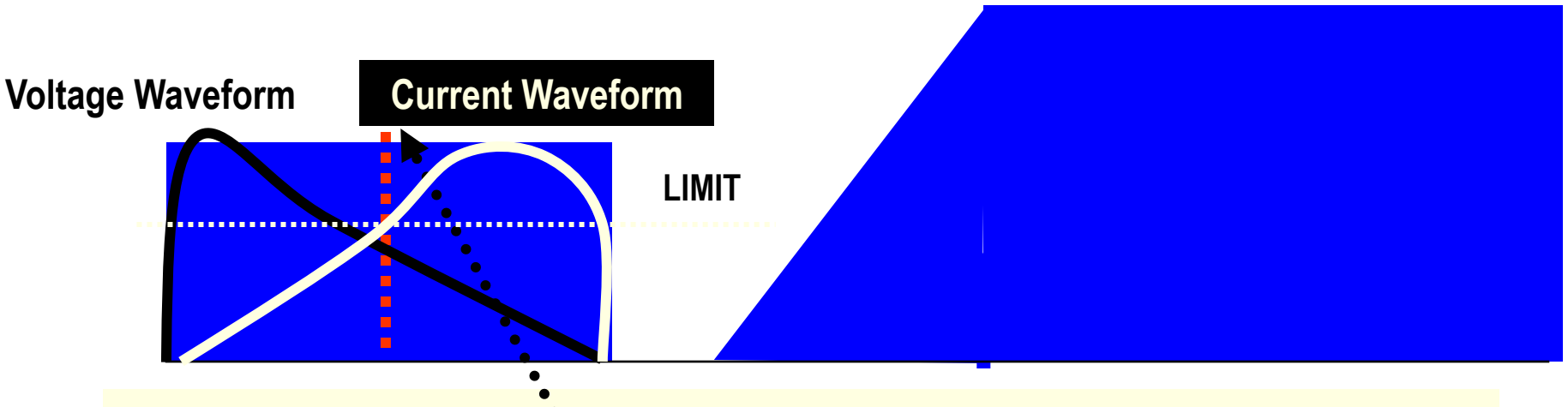
Active Part Conditioner (APC)

First Pulse

Constant Power

Second Pulse

Constant voltage, current or power



전류 상한값 에서 첫번째 펄스는 종료된다

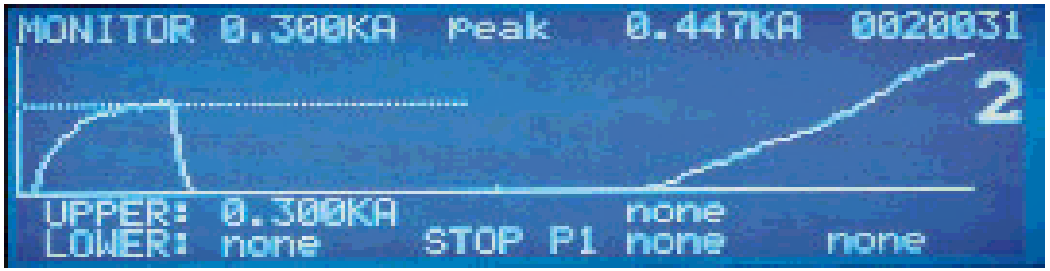
단, 시료의 오염이 심하면 전류 상한값 에서 용접 시간이 더 지속된다

Active Part Conditioner (APC)

용접시료마다 서로 다른 두께의 산화층을 1차 용접 펄스 (정전력 모드 필수)에서 자동 시간 조절로 균일하게 제거한 후 2차 용접펄스 진행

Advantages:

- Compensates for material conditions 용접시료의 상태를 보상
- Prevents weld splash 용접시 튀는 문제 예방
- Increases process yield 공정율의 증가
- Helps minimize the impact of varying parts 용접시료가 변화면서 생기는 용접시 충격 최소화



SPC Datacom

(Statistical Process Control)

- Windows based software
- Data logging and storage of weld history records
- Remote programming capability and weld schedule library
- SPC charts and graphs
- RS-232 : a single contact to a computer
- RS-485 : multiple contact to a computer

Q & A

감사합니다