Skin friction reduction using a novel Si-Polyurea AF Paint

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Why energy saving ship technology ? : Fuel saving

- **A 10,000 TEU container carrier with service speed of 24 knots**
  - ✓ 100,000 HP Main Engine
  - ✓ 300 Ton/Day Fuel Consumption : 45 Million $/year (500$/ton, Bunker C)

    → 10% drag reduction or propulsion efficiency up = 4.5 Million $/year saving

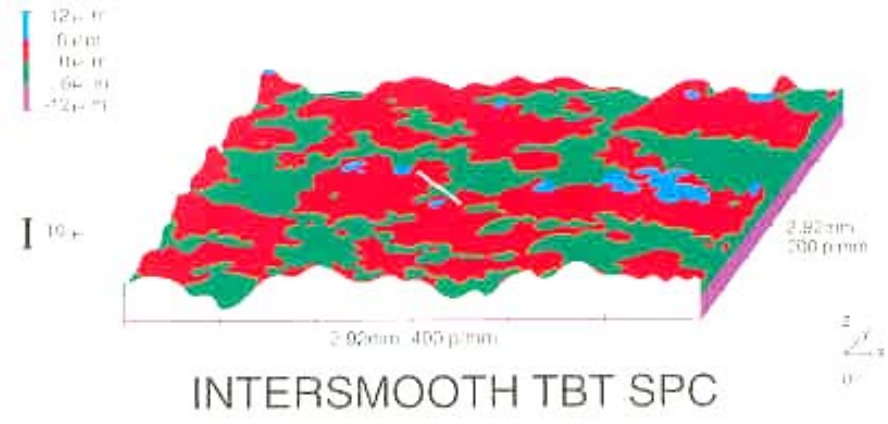
- **Worldwide ship fleet (2003 statistics)**
  - ✓ Global ocean shipping ('03) : 2.1 Billion barrel/year → 100 Billion $/year (50$/barrel)
  - ✓10% drag reduction = 10 Billion $/year saving
  - ✓Emission Rate Reduction

Silicone Antifouling Paint (I)

- **Intersleek 700 : International Paint (U.K.)**
  - Novel AF Paint : non-toxic, foul-release type silicone AF Paint

- **Basic Research : Newcastle Univ. & International Paint (U.K.)**
  - Correlation between surface roughness & skin friction
  - Surface roughness of various surface treatments
    - Bare plate : 17μm
    - Si AF Paint (Intersleek 700) : 44μm
    - SPC AF Paint (Intersmooth TBT SPC) : 75μm

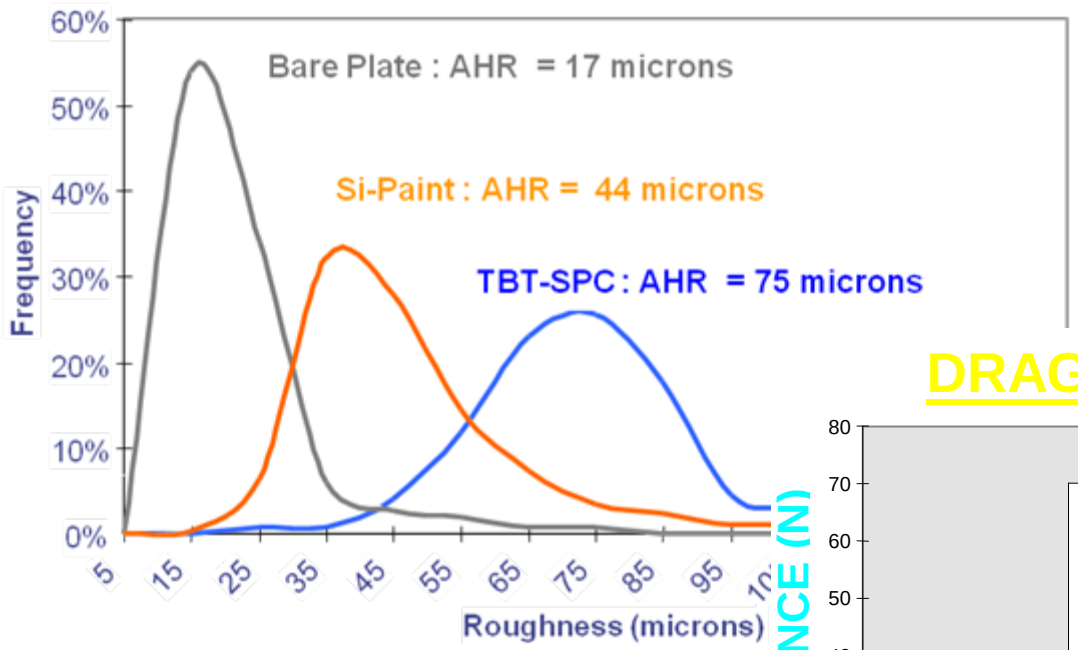
INTERSLEEK 700



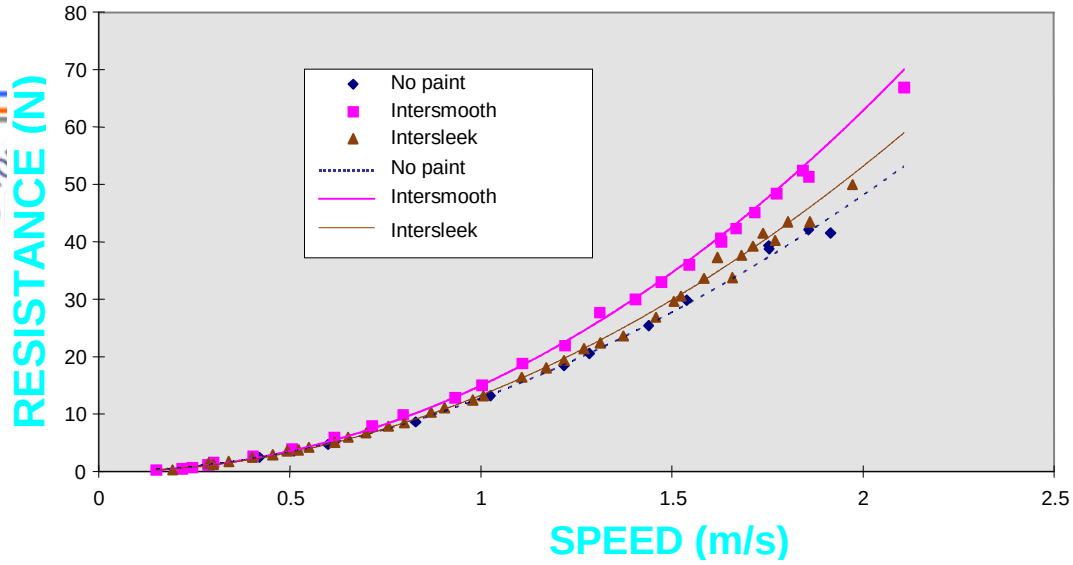
INTERSMOOTH TBT SPC

Silicone Antifouling Paint (II)

- **Basic Research : International Paint (U.K.)**
  - Surface roughness vs. Skin friction



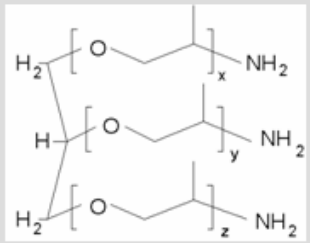
DRAG (RESISTANCE) vs SPEED

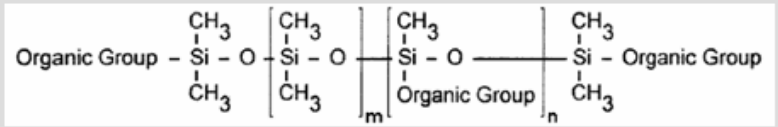


Si-Polyurea AF Paint (I)

- **S-P SLIP : stronger than Intersleek**
  - Silicone Polyurea resin synthesis technology : Silicone + Polyurethane
  - Excellent mechanical properties
    - Shock resistance, wear endurance
    - Adhesion Strength : 10MPa (>5MPa, Intersleek)
    - Workability : VOC-free, Ultra-fast drying (tag-free less than 2min.)
    - Easy formation of very thick film (> 500μm)
    - **Elongation : 0% (SPC AF) < 300% (Si-Polyurea) < 600% (Si Rubber)**
    - **Hardness (Shore D) : 20 (Si Rubber) < 40 (Si-Polyurea) < 100 (SPC AF)**

RESIN



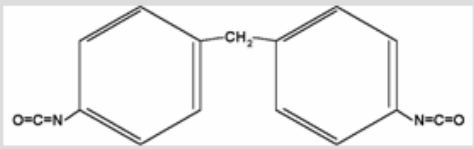


Polyamine

Silicone Fluids

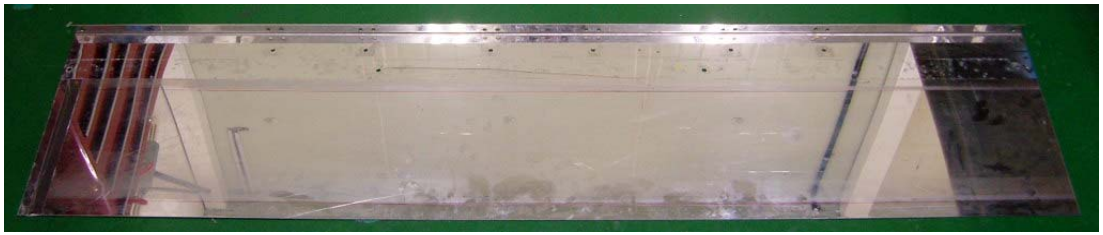
CATALYST

Isocyanate Group



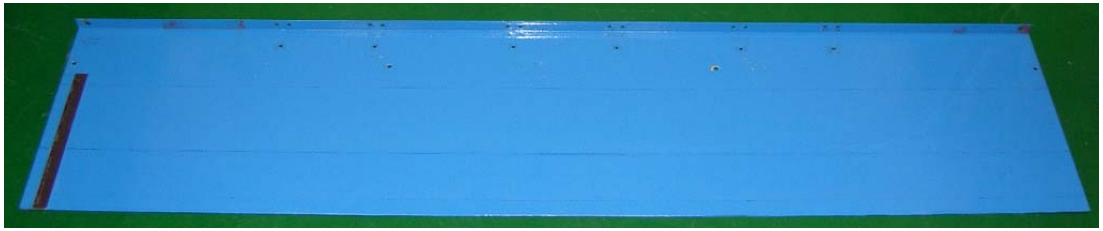
Skin Friction of Flat Plate (I)

- **Flat Plate for Drag Measurement in Towing Tank**
  - Dimension : 1,520 mm (L)× 225 mm (W)×1.6mm (T)
  - Roughness : hull roughness analyzer (BMT SeaTech.)

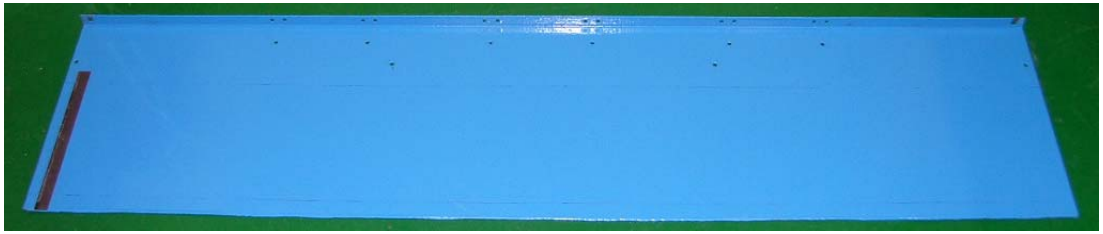


Bare plate
(roughness~1.5μm)

General SPC Paint
(roughness~38μm)



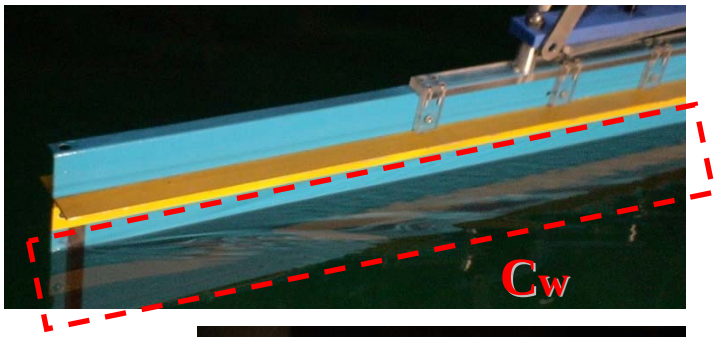
Si-Polyurea
(roughness~30μm)



Si-Polyurea
(roughness~47μm)

Skin Friction of Flat Plate (II)

- **How to Estimate Skin Frictional Drag**
  - Schultz, M. P., 2004, "Frictional Resistance of Antifouling Coating System", Journal of Fluids Engineering, Vol.126, pp.1039-1046



$$C_T = C_f + C_w$$

Same values

$$C_T = C_f(200) + C_w$$

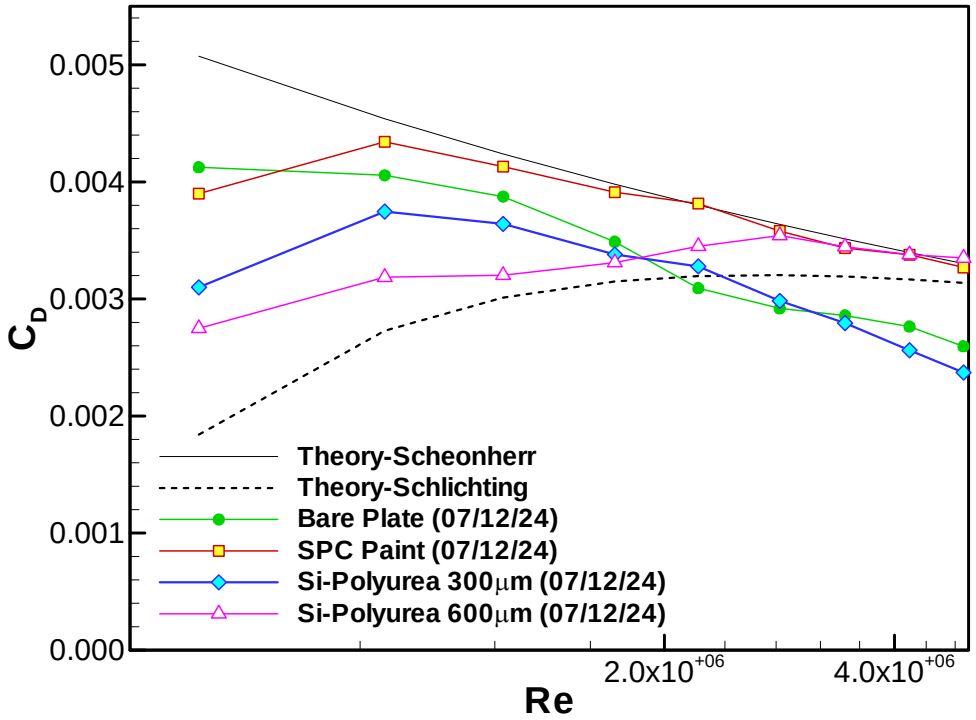
$$C_T = C_f(175) + C_w$$

$$C_T = C_f(25) + C_w$$

$$C_f(200) + C_w = C_f(175) + C_f(25) + 2C_w$$

Skin Friction of Flat Plate (III)

- **W/O turbulence trip : Transition**
  - **Film thickness 300μm**
    - max. 8.6% reduction (rel. bare plate), max. 27.4% reduction (rel. SPC paint)
  - **Film thickness 600μm**
    - Drag reduction effect decreases



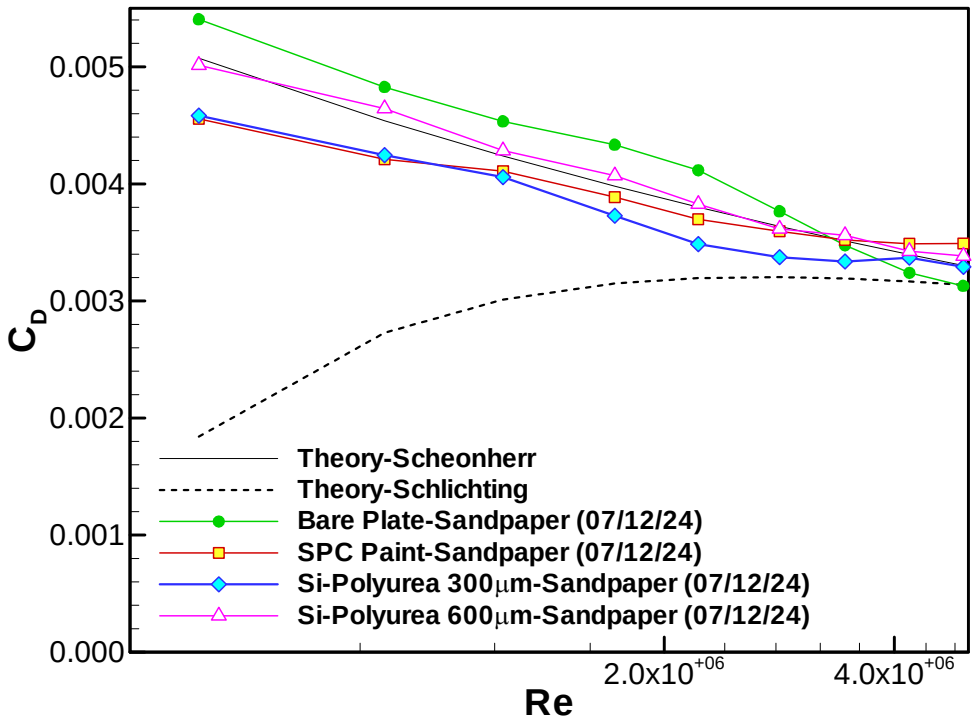
Re×10^{-6}	Bare Plate C_f ×10^3	SPC AF Paint C_f ×10^3	Si-Polyurea Paint (300μm)		
			C_f ×10^3	% drag reduction (relative to bare plate)	% drag reduction (relative to SPC paint)
0.492	4.124	3.899	**3.099**	**24.9**	**20.5**
0.862	4.056	4.343	**3.747**	**7.6**	**13.7**
1.23	3.874	4.131	**3.641**	**6.0**	**11.9**
1.72	3.488	3.912	**3.380**	**3.1**	**13.6**
2.22	3.091	3.815	**3.278**	*-6.0*	**14.1**
2.83	2.920	3.580	**2.983**	*-2.2*	**16.7**
3.45	2.859	3.435	**2.794**	**2.3**	**18.7**
4.18	2.764	3.377	**2.562**	**7.3**	**24.1**
4.92	2.595	3.269	**2.372**	**8.6**	**27.4**

Re×10^{-6}	Bare Plate C_f ×10^3	SPC AF Paint C_f ×10^3	Si-Polyurea Paint (600μm)		
			C_f ×10^3	% drag reduction (relative to bare plate)	% drag reduction (relative to SPC paint)
0.492	4.124	3.899	**2.749**	**33.3**	**29.5**
0.862	4.056	4.343	**3.186**	**21.5**	**26.6**
1.23	3.874	4.131	**3.203**	**17.3**	**22.5**
1.72	3.488	3.912	**3.311**	**5.1**	**15.4**
2.22	3.091	3.815	**3.450**	*-11.6**	**9.6**
2.83	2.920	3.580	**3.542**	*-21.3*	**1.1**
3.45	2.859	3.435	**3.446**	*-20.5*	*-0.3*
4.18	2.764	3.377	**3.379**	*-22.3*	*-0.1*
4.92	2.595	3.269	**3.350**	*-29.1*	*-2.5*

* Negative value of drag reduction % indicates drag increase.

Skin Friction of Flat Plate (IV)

- **W/ turbulence trip : Turbulent**
  - **Trip → transition enhancement**
  - **Drag reduction effect : Decreases**



Re×10^{-6}	Bare Plate C_f ×10^3	SPC AF Paint C_f ×10^3	Si-Polyurea Paint (300μm)		
			C_f ×10^3	% drag reduction (relative to bare plate)	% drag reduction (relative to SPC paint)
0.492	5.405	4.555	**4.583**	**15.2**	*-0.6*
0.862	4.827	4.210	**4.246**	**12.0**	*-0.9*
1.23	4.533	4.108	**4.058**	**10.5**	**1.2**
1.72	4.334	3.887	**3.728**	**14.0**	**4.1**
2.22	4.116	3.698	**3.485**	**15.3**	**5.8**
2.83	3.765	3.596	**3.374**	**10.4**	**6.2**
3.45	3.475	3.522	**3.337**	**4.0**	**5.3**
4.18	3.240	3.489	**3.370**	*-4.0*	**3.4**
4.92	3.128	3.450	**3.292**	*-5.2*	**5.7**

Re×10^{-6}	Bare Plate C_f ×10^3	SPC AF Paint C_f ×10^3	Si-Polyurea Paint (600μm)		
			C_f ×10^3	% drag reduction (relative to bare plate)	% drag reduction (relative to SPC paint)
0.492	5.405	4.555	**5.014**	**7.2**	*-10.1*
0.862	4.827	4.210	**4.644**	**3.8**	*-10.3*
1.23	4.533	4.108	**4.285**	**5.5**	*-4.3*
1.72	4.334	3.887	**4.070**	**6.1**	*-4.7*
2.22	4.116	3.698	**3.827**	**7.0**	*-3.5*
2.83	3.765	3.596	**3.615**	**4.0**	*-0.6*
3.45	3.475	3.522	**3.561**	*-2.5**	*-1.1*
4.18	3.240	3.489	**3.425**	*-5.7*	**1.8**
4.92	3.128	3.450	**3.384**	*-8.2*	**3.0**

* Negative value of drag reduction % indicates drag increase.

Marine Coatings Labs at ASERC

Mixer

Mill

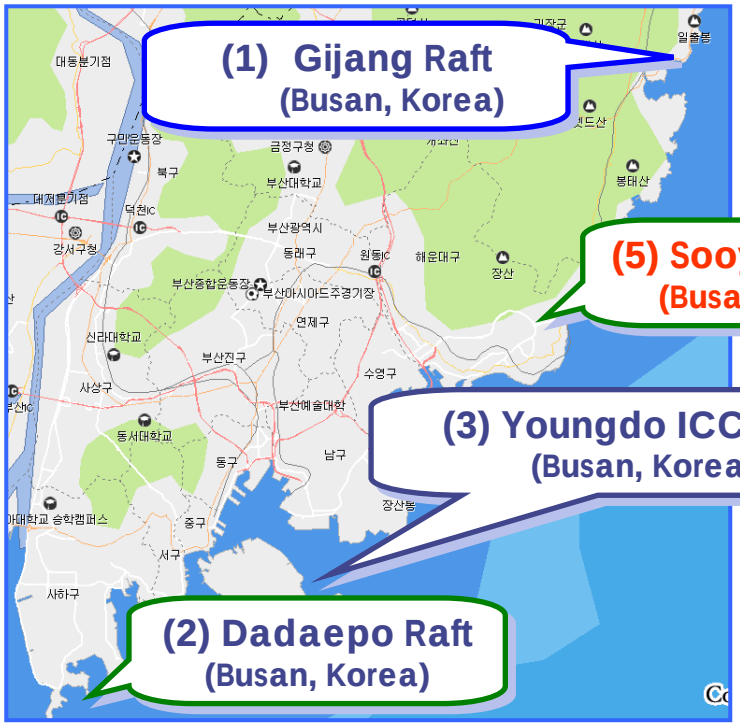
Potentiostat/Galvanostat

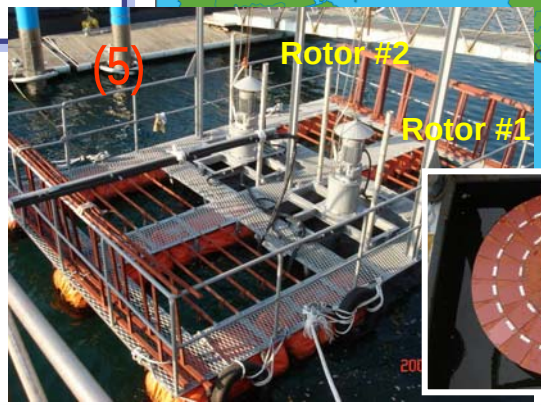
Coating Thickness Gauge

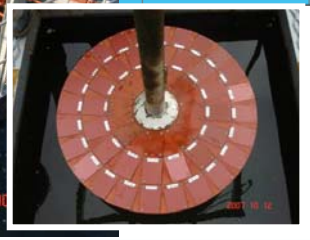
Vibrating Sieve

Auto Spray Booth

Facilities : 4 Static & 1 Dynamic Immersion Testing Platforms







➢ Immersion Test

Place	Developing AF Paints			Conventional AF Paints		
	Cu-Free type			Cu-Free type		Cu type
	#T-15	#T-17	#T-18	#1	#2	#1
#1 Raft (Gijang)						
#2 Raft (Dadaepo)						


ASERC
Thank you for your attention