Precipitation Gauge

Application of an Ultrasonic Flow Measurement Technique

July 2014

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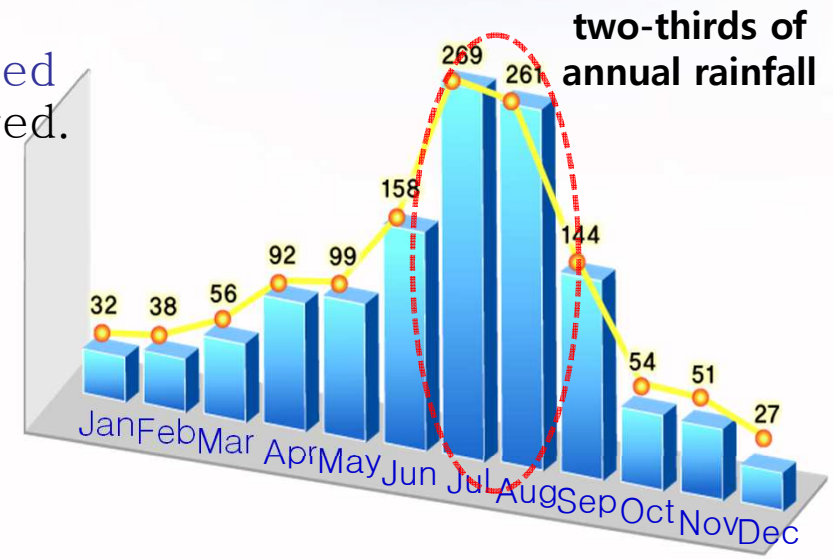
1. Introduction

- **Rainfall characteristics of Korea**
- **The number of installed precipitation gauges**
- **Recent topics**

Introduction

1. Rainfall characteristics of Korea

- Depending on the season, annual rainfall severely deviates, with two-thirds of the annual rainfall concentrated during the summer rainy season.
- Because of the global warming, localized and severe tropical rainfall has appeared.
- Accurate real-time rainfall data is required for more reliable flood prediction and floodgate control



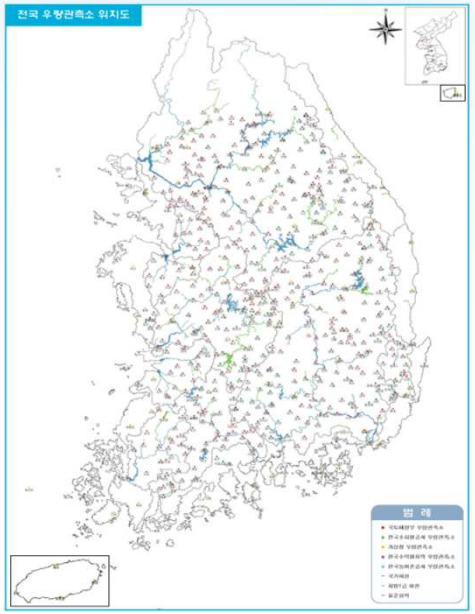
Introduction

2. Number of the installed precipitation gauges in Korea

※ 2009 standard

Section	Amount	Percentage
Local governments	1,861	51%
KMA*	544	15%
MOLIT*	430	12%
K-water	199	5%
Others	608	17%
Total (domestic)	3,642	100%

* KMA : Korea Meteorological Administration
* MOLIT : Ministry of Land, Transport and Maritime Affairs in Korea



Introduction

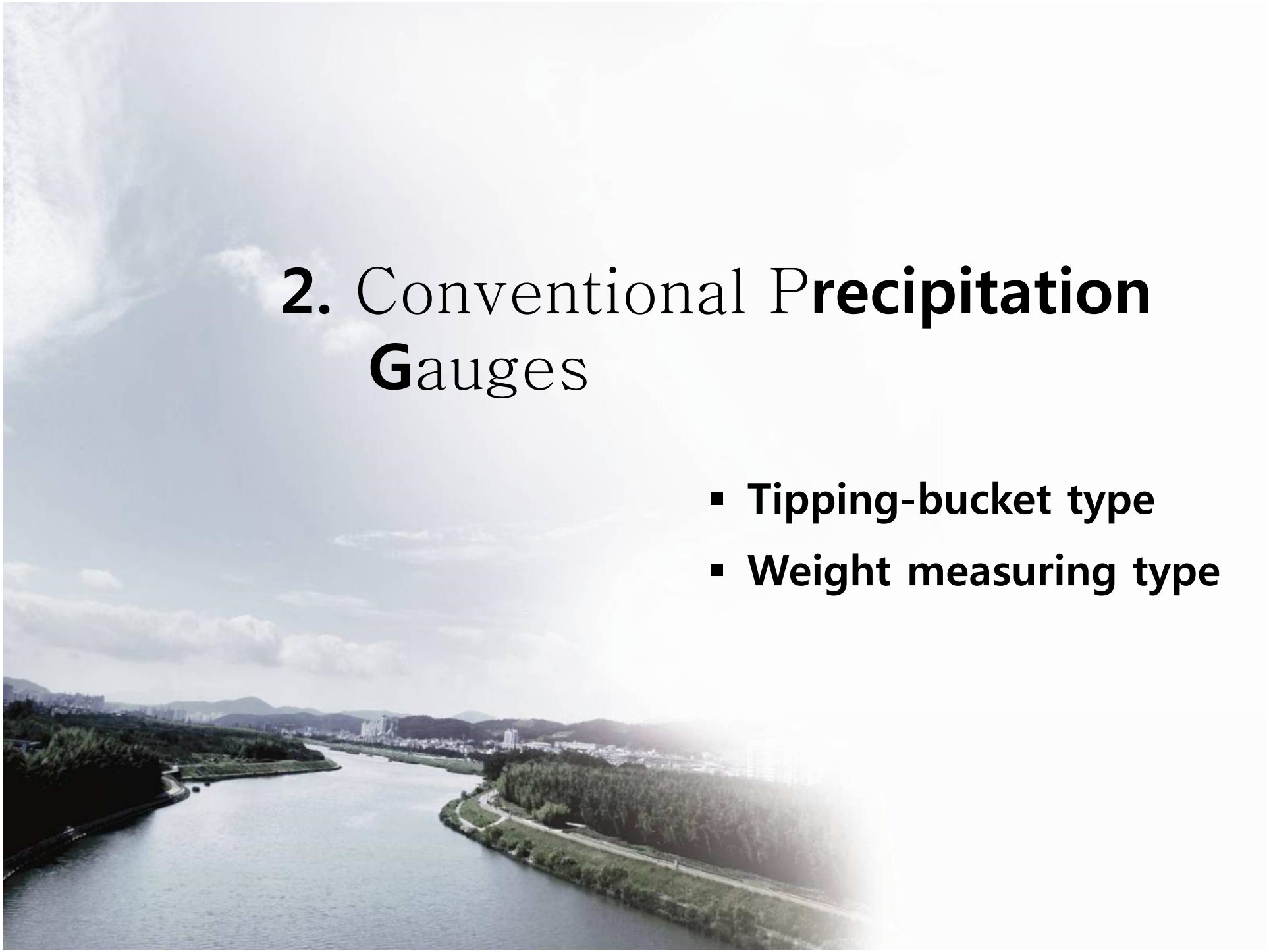
3. Recent topics

- MOLIT long-term plan
  - **Precipitation gauges will be installed to increase the density which will lead to more effective water resource management and accurate flood predictions**
  - **Observation and utilization equipment will be upgraded by developing IT technologies**

※ reference : J. B. Kim, "Evaluation of Rain-gauge Networks in the Soyanggang Dam River Basin." M.D. Dissertation, Department of Civil engineering, Graduate School of Chungnam National University, Daejeon, Korea 2007.

- Essay(excerpted)
  - **Compared with modern observations, it is true that accuracy and precision is not good enough in terms of observation intervals and precision of observed rainfall**
  - **At present, a method that can overcome the low precision of Precipitation gauges' rainfall data is unclear.**

※ reference : G. H. Lim, "The 17th Century Dry Period in the Time Series of the Monthly Rain and Snow Days of Seoul's Atmosphere." Korean Meteorological Society Vol. 22, No. 3 (2012) pp. 383



2. Conventional Precipitation Gauges

- **Tipping-bucket type**
- **Weight measuring type**

Conventional Precipitation Gauges

1. Tipping-bucket type

Principle

- Water collecting → Bucket Tipping → Self-actuated switch operation → Pulse output
- Resolutions are divided depending on the bucket size
  For example: 0.1/0.2/0.5/1.0mm/h

Pros

- Easy visual observation, cheap price (Less than $ 2,000)
- External power supply is unnecessary (Except in winter)

Cons

- Precise measurement is impossible
  - Increase in rainfall intensity → Increase in the number of tipping buckets→ Cumulative error
  - Increase in rainfall intensity → unfilled buckets could tip or water jumps out of the bucket
  - **Measurement range is limited by rainfall intensity**

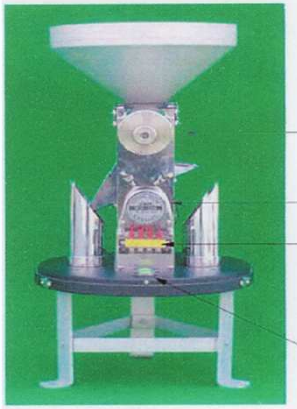
Resolution	Measurable rainfall	Remarks
0.1mm	0.1mm/h ~ 50mm/h	Requires the simultaneous use of three devices ☞ Non-continuous observation data
0.5mm	0.5mm/h ~ 250mm/h	
1mm	1mm/h ~ 500mm/h	

- Difficult to maintain (dust or insects cling to Moving parts → Friction occurs)
- Difficult to Calibrate (Plenty of distilled water and equipment is needed)

Share

- **Approximately 70%, at least**

Pictures



< Figure> Weight measuring type precipitation gauge

< Figure> **Calibration System**

※ reference : D. M. Woo, "A Study on the characteristics by the rainfall intensity of the tipping-bucket rain gauge," M.D. dissertation, Graduate School of Industry and Engineering, Seoul National University of Technology, 2001

Conventional Precipitation Gauges

2. Weight measuring type

Principle

- Weight is measured through the load sensor (load cell, etc.)→ Conversion to rainfall

Pros

- Low failure factor because mechanical moving parts are less than the Tipping-bucket type.
- Precise measurements

Cons

- Measurement errors due to wind
- Temperature compensation is required for each Load sensor
- Drainage needed when Bottle is filled (Manual / Auto) ☞ Non-continuous measurements
- Errors occur as a result of residues (dust, frost, etc.)
- maintenance is needed every few months
- Very expensive (about $10,000 USD)

Share

- Approximately less than 30%

Pictures

< Figure> Weight measuring type precipitation gauge

※ reference : “Guide to Meteorological Instruments and Methods of Observation,” No. 8, Part. I, Ch. 6, World Meteorological Organization, pp. 33-34, 2008.

3. Configuration and Development Objectives

- Development objective
- Configuration objective

Configuration and Development Objectives

1. Development objective

- **Improving accuracy (especially for heavy rainfall conditions) and capabilities for a wider range of rainfall**

  ※ WMO(**World Meteorological Organization**) **Recommendations** & KMA **criteria** : resolution of 0.1mm/h and **Within the error range of** ± 5%

- Full Digitalization of the measurement and communication system

  ※ various communication methods (serial, wireless, etc.) ensure rain fall data transmissions are never lost

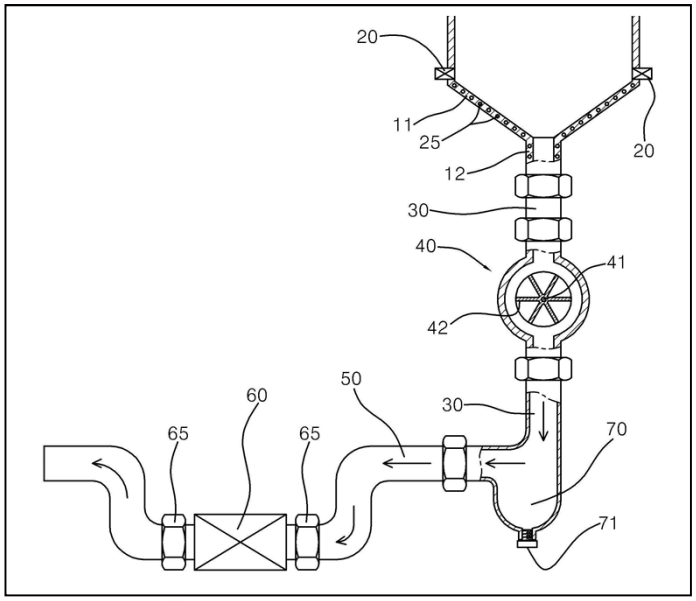
- Simplifying the structure for easy maintenance

- Amalgamation of the latest measurement technologies with advanced IT technologies

Configuration and Development Objectives

2. Configuration objectives (overview)

- Appropriate amount of rainfall is collected in the turbine(42) and shed below to obtain the minimum flow rate
  ☞ resolution of 0.1mm/h
- Convert the accurately measured flow using an ultrasonic sensor(60) installed in the precipitation unit
- Residues are accumulated in the checking section(70) and are discharged through the outlet port(71)



<Figure> Configuration of the Precipitation Gauge

$$Q = \pi \times r^2 \times h$$

$$\therefore h = \frac{Q}{\pi \times r^2}$$

Q : Measured flow

r : Hole radius

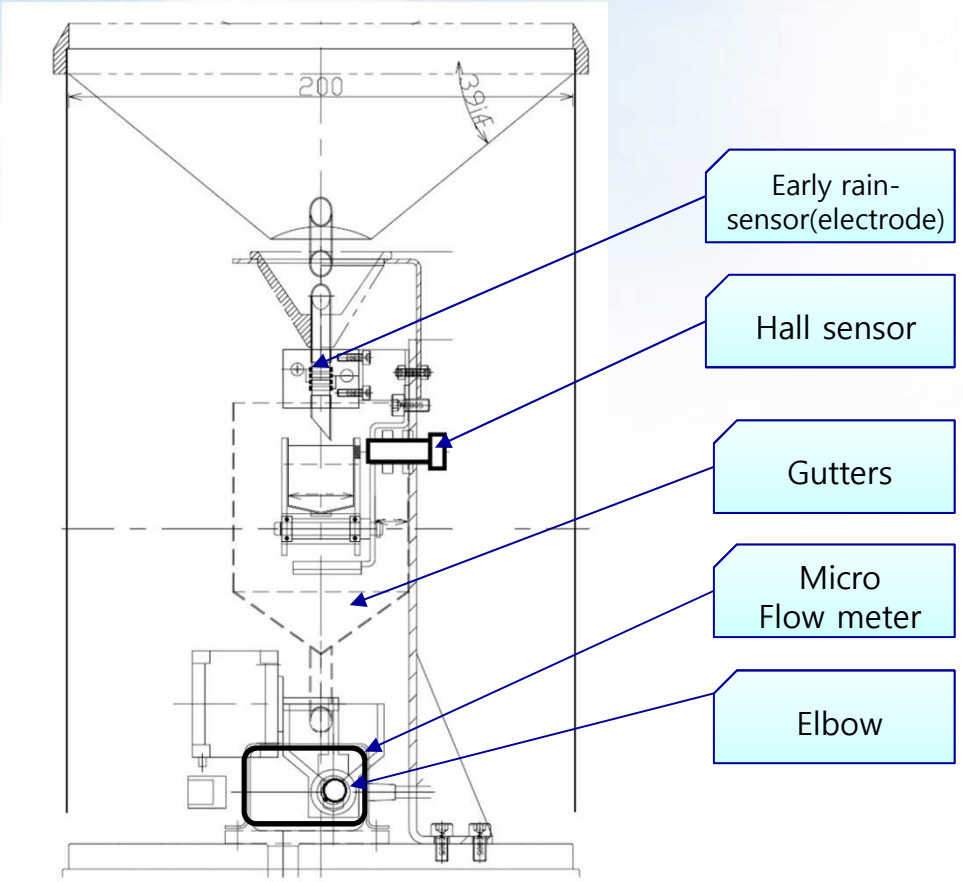
h : Precipitation

Configuration and Development Objectives

2. Configuration objectives (details)

- Ensure the meter is filled with water by applying an Elbow in the outlet pipe
- Detect snow by installing an optical sensor → **Heating coil operation → Maintain the internal temperature**
- Early rain detection by installing a ring electrode sensor
  ☞ **Power saving function (optional)**
- **Motion detection via a hall sensor**
  ☞ **diagnostic features (optional)**
- **Installation of solar cells or a built-in battery**
  ☞ **independent power**
- **Various communication methods (zigbee, etc.)**
  ☞ completely wireless

※ **Dimensions** : **Diameter of** 200 (**same with the existing standards**)



<figure> **Details of the measurement device**

4. Performance Evaluation

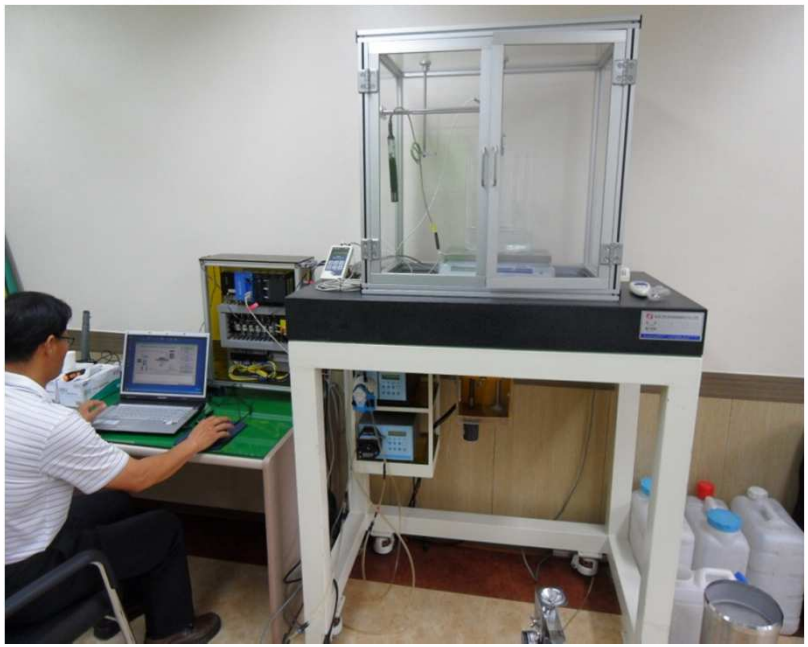
- Indoor performance evaluation
- Field verification (Yongdam Dam)
- Field verification (KMA)

Performance Evaluation

1. Indoor performance evaluation

- Purpose : Analysis of error rates by rainfall intensity
- Place : K-water Precipitation Gauge Correctional Center
- Period : 30. July. 2012 ~ 08. Aug. 2012
- Equipment : Standard indoor calibration system

  ※ Consists of precision balances, 2 metering pumps, PLC, HMI



K water

시험 성적서

대전광역시 유성구 유성대로 1689번길 125
Tel: 042-870-7000 Fax: 042-870-7149

시험 일자	2013. 09. 17
시험 번호	Rain-2013-001

1. 의뢰자
기관명 : 주식회사 이엔에코 주 소 : 경기도 성남시 중원구 하대동 150, 분당테크노파크 A-107

2. 측정기
기기명 : 강우량계(초음파 유량) 제작형식 : Ray-Q 기기번호 : EF-R-008 수수구 수집구경 : 298 ㎜

3. 시험환경
● 교정장소: 교정표준실 ● 실내온도: (24.0 ± 1.0) ℃ ● 상대습도: (44 ± 7) % R.H

4. 시험에 사용한 표준장비 명세

사용장비명	형식	기기번호	교정유효일자	교정기관
순 수	Millipore, Gradient	F4HN19926K	2013.12.06	에이치피엠㈜
표 준 분 동	두안테크, SUS	1000	2014.03.21	에이치피엠㈜
전 자 저 울	Mettler Toledo, S88001-I	1127163133	2014.04.07	에이치피엠㈜
온습도대기압계(온습)	Thommen, HM30	1028487	2013.11.21	에이치피엠㈜
온습도대기압계(수온)	Thommen, HM30	1028487	2013.11.20	에이치피엠㈜
온습도대기압계(기압)	Thommen, HM30	1028487	2013.12.25	한국표준과학연구원

5. 시험방법
전도식 강우량계 교정 지침서 (Kwater-CW-E012)에 따라 국가측정표준 기관으로부터 소급성이 확보된 아래의 표준장비를 이용하여 교정 되었음.

6. 시험결과

번호	강우강도(㎜/h)	수집중량(g)	기준부피(환산)	Ray-Q(g)	상대편차(%)
1	20.0	35.0	35.1	33.90	-3.40 %
2	40.0	70.4	70.6	68.60	-2.82 %
3	60.0	105.3	105.6	103.50	-1.98 %
4	80.0	141.0	141.4	137.10	-3.03 %
5	100.0	174.8	175.3	173.00	-1.30 %

※ 실험시 물의 온도는 24.1±0.3 ℃ 이며, 물의 밀도는 0.997273을 적용 함.

확 인	작성자	승인자
직 위:	교정실무자	교정실무자
성 명:	김일한	홍성택

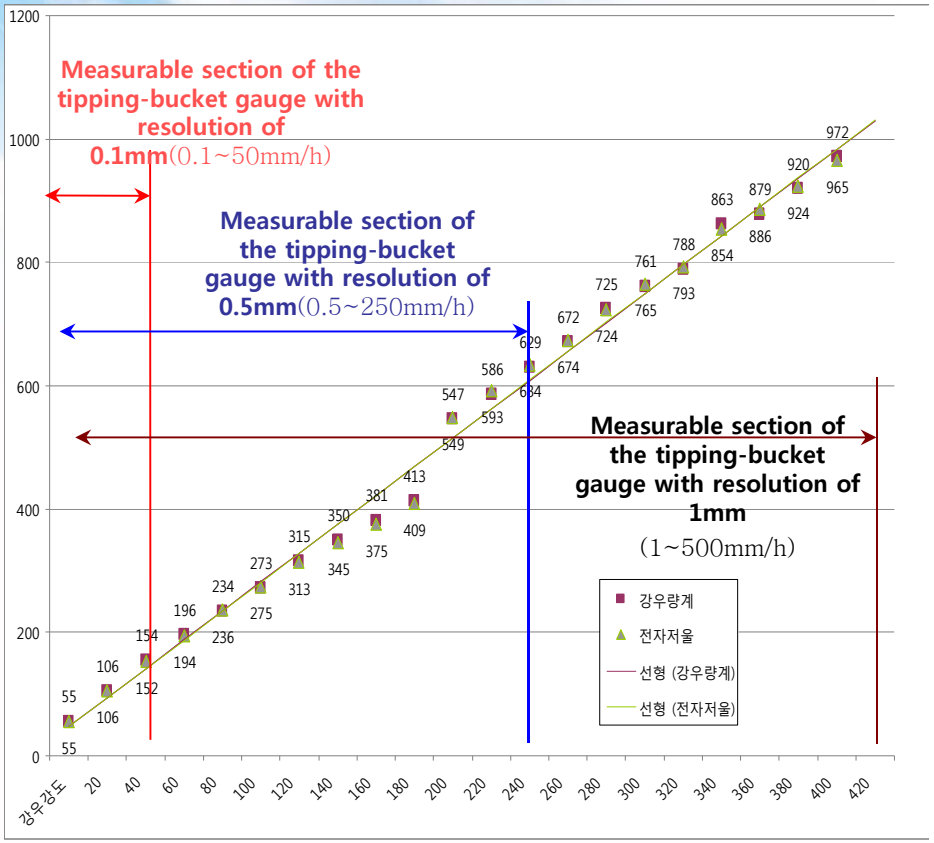
※ 주의: 이 성적서는 측정기의 정밀 정확도에 영향을 미치는 요소(과부하,온도,습도 등)의 급격한 변화가 발생한 경우나, 사용자를 넘는 환경에서의 적용시에는 무효가 됩니다. 이성적서의 시험결과는 시험된 시험품목에 한합니다.

<Figure> Performance Evaluation Center and the test report

Performance Evaluation

- Test results

Rainfall intensity [mm/h]	Developed precipitation gauge [ml]	Electronic scales(True value)[g]	Errors	Error rate	Reference
20	55	55	0	0.00%	
40	106	106	0	0.00%	
60	154	152	-2	-1.32%	
80	196	194	-2	-1.03%	
100	234	236	-2	-0.85%	
120	273	275	-2	-0.73%	
140	315	313	2	0.64%	
160	350	345	5	1.45%	
180	381	375	6	1.60%	
200	413	409	4	0.98%	
220	547	549	-2	-0.36%	1 Pump added
240	586	593	-7	-1.18%	
260	629	634	-5	-0.79%	
280	672	674	-2	-0.30%	
300	725	724	1	0.14%	
320	761	765	-4	-0.52%	
340	788	793	-5	-0.63%	
360	863	854	9	1.05%	
380	879	886	-7	-0.79%	
400	920	924	-4	-0.43%	
420	972	965	7	0.73%	



➢ More accurate and reliable measurements are possible for rainfall ranging from **0.1~420mm/h or more**

Performance Evaluation

2. Field verification (Yongdam Dam)

- **Purpose : Evaluation of field applicability**
- **Place : Bu-gwi Rainfall Measurement Station (Yongdam Dam)**
- **Period : Sept.2012~June.2013**
- **Equipment : Developed precipitation gauge, existing precipitation gauge, Beaker, etc.**

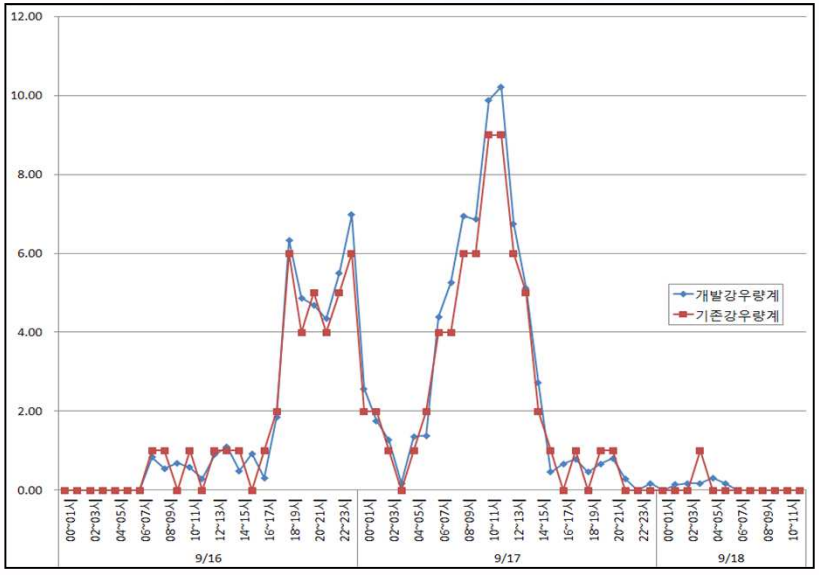
  ※ Logging system consists of PLC and HMI

<Figure> Precipitation measurement system installed in Bu-gwi Station

Performance Evaluation

- Comparative analysis
  - **A 6 ℓ beaker was used as the installation capacity for the two precipitation gauges in order to compare the values of the water in the beaker and measured values of the gauges**
- Results of the analysis
  - **Accurate measurement of precipitation was possible throughout the entire period on a real-time basis**

<Figure> **Beaker experiment**



<Figure> **Observed precipitation date during the typhoon 'Samba'**

Performance Evaluation

3. Field verification (KMA- Korea Meteorological Administration)

- **Purpose : Evaluation of field applicability at an internationally recognized Station**
- **Place : Go-chang standard observatory,** KMA
- **Period : July.2013~present**
- **Equipment : Developed precipitation gauge, logging system**

<Figure> Installed precipitation gauge in Go-chang, KMA

5. Summary of Results and Future Plans

- Analysis results of the developed gauge
- State of intellectual property rights
  - Domestic patent
  - International patent
- Commercialization promotion

Summary of Results and Future Plans

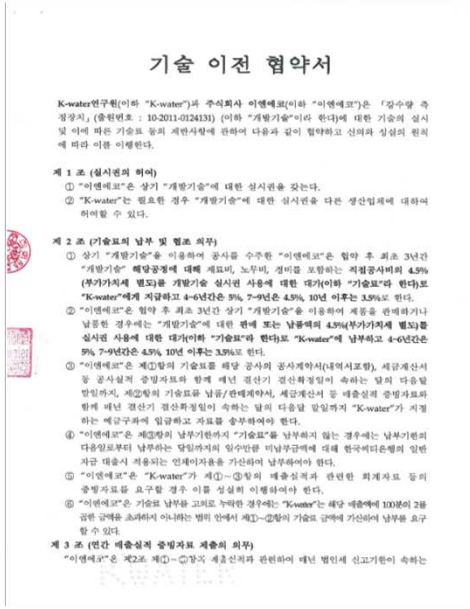
1. Analysis results of the developed gauge

- Accurate measurements are possible for a wider range of rainfall intensity (0.1~420mm/h)
  - Developed gauge : Capable of measuring continuously with an improved margin of error(5% → 2%)
- Digitalization of all equipment from measurement units to transfer units
- **Various communication methods**(serial communication, Wi-Fi, Zigbee, satellite, etc..) are easy to adopt
- **E**rrors caused by the friction of moving parts were eliminated, and **failure factors were reduced**
- **Emptying of the bucket is not required**

Summary of Results and Future Plans

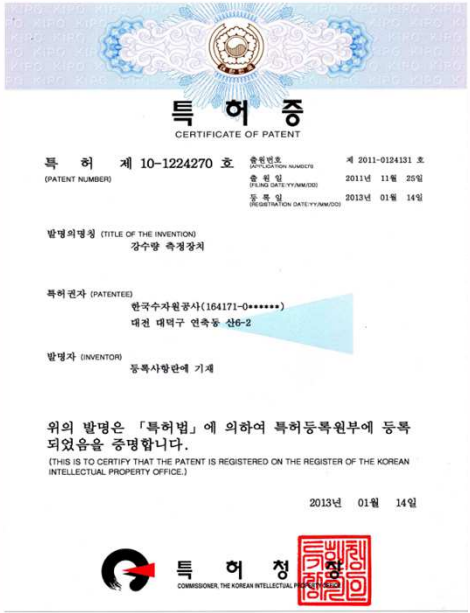
2. **Intellectual property rights** (patents) - Domestic

- **Nov '11 : Applied for a domestic patent (**no.10-2011-0124131**)**
- **Oct '12 : K-water ↔ Technology transfer to private company (e&eco)**
- **Nov '12 : Applied for international patent(PCT)**(no. PCT/KR2012/009510)
- **Jan '13 : Domestic patent registration**(no.10-1224270)



기술 이전 협약서

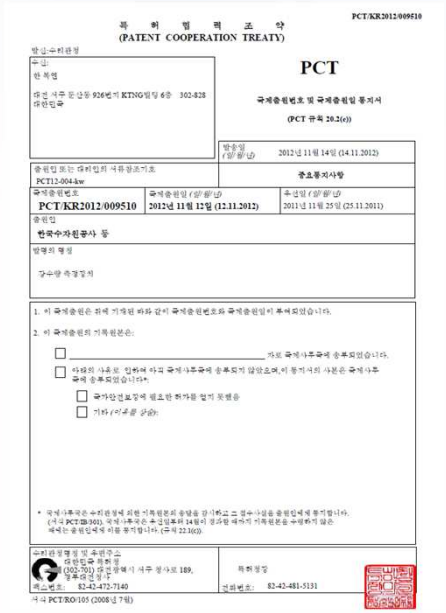
Technology transfer agreements



특 허 증

CERTIFICATE OF PATENT

Domestic patent



특 허 협 력 조 약

(PATENT COOPERATION TREATY)

PCT

International Patent(PCT)

Precipitation Gauge

Summary of Results and Future Plans

3. Commercialization promotion

- **Nov '12 : Seminar in KMA (11.20)**
- **Oct '13 : Cost estimation for sales ☞ Unit price: $3,350 USD**
- **~June '14 : Applied to Youndam, Youngju, Buan, and Dongwha dam in Korea**
- **October '13 : Approved by Korean government agency**
- **November '13 : Confirmation of Success as a national project (Business Administration, Korea government).**
- **July '14 : TECO-2014, CIMO's International Conference**

☞ Adoption of International Standard Instruments in Precipitation Gauge

■ 기상관측표준화법 시행규칙 [별지 제2호서식]

제1239호

기상측기검정증명서

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	⑤주 소	경기도 성남시 분당구 야탑남로 233, 107호		
	⑥기 상 측 기 명	강수량계		

검정내용	⑦검정요소	⑧제조회사	⑨규격(모델)	⑩제조연월일	⑪제조번호	⑫비 고
	강수량	(주)이엔에코	Ray-Q	2013. 9.	R-2013-003	초음파 유량식
		이	하	여	백	

※ 붙임 : 기상측기검정성적서

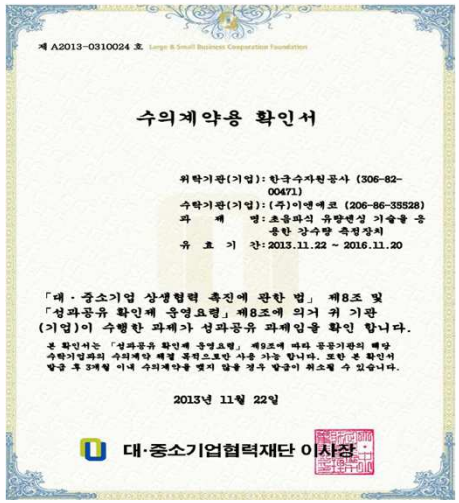
위 기상측기는 「기상관측표준화법」 제13조제1항 및 같은 법 시행령 제6조제3항에 따라 검정한 결과 검정에 합격한 것임을 증명합니다.

2013년 10월 24일

□ 기상청장
■ 한국기상산업진흥원장

※ 이 증명서의 유효기간은 증명발행일부터 3년 입니다.

Authorized **Certification**



제 A2013-0310024 호

수의계약용 확인서

위탁기관(기업) : 한국수자원공사 (306-82-00471)
수탁기관(기업) : (주)이엔에코 (206-86-35528)
과 제 명 : 초음파식 유량센싱 기술을 응용한 강수량 측정장치
유 효 기 간 : 2013.11.22 ~ 2016.11.20

「대·중소기업 상생협력 촉진에 관한 법」 제8조 및 「성과공유 확인제 운영요령」 제8조에 의거 귀 기관(기업)이 수행한 과제가 성과공유 과제임을 확인 합니다.

본 확인서는 「성과공유 확인제 운영요령」 제9조에 따라 공공기관의 해당 수탁기업과의 수의계약 체결 목적으로만 사용 가능 합니다. 또한 본 확인서 발급 후 3개월 이내 수의계약을 맺지 않을 경우 발급이 취소될 수 있습니다.

2013년 11월 22일

대·중소기업협력재단 이사장

Optional contract confirmation


Thank You