# Introduction to The Tipping Bucket Rain Gauge

2011

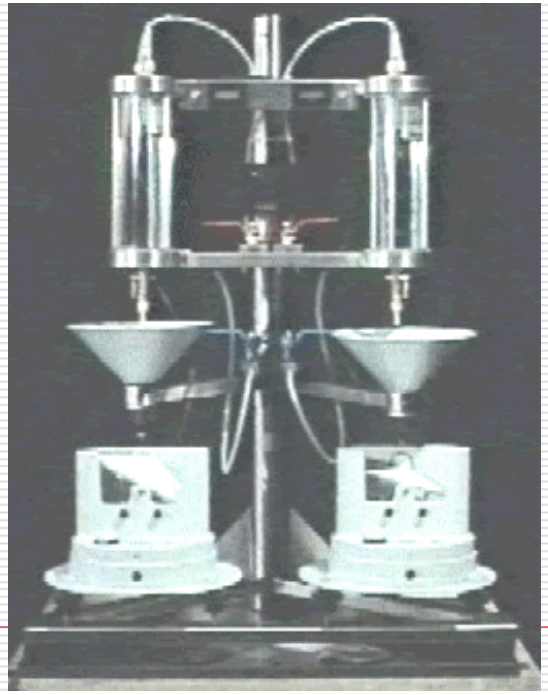
Dr John Gorman, ARIC

# Rainfall

- **Manual Rain Gauge**

- **Field Calibration Device**

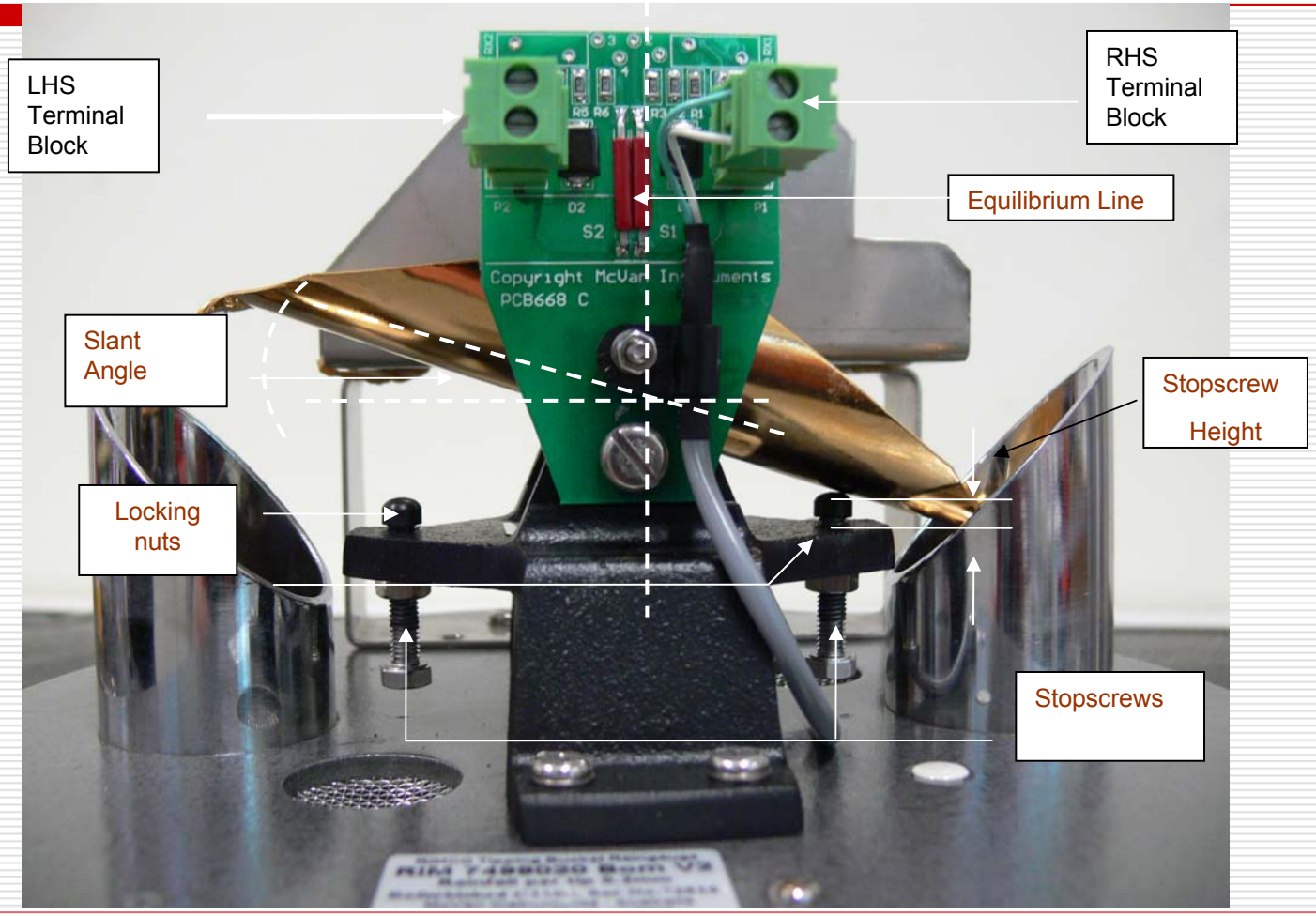
- **HS TBRG Tester**



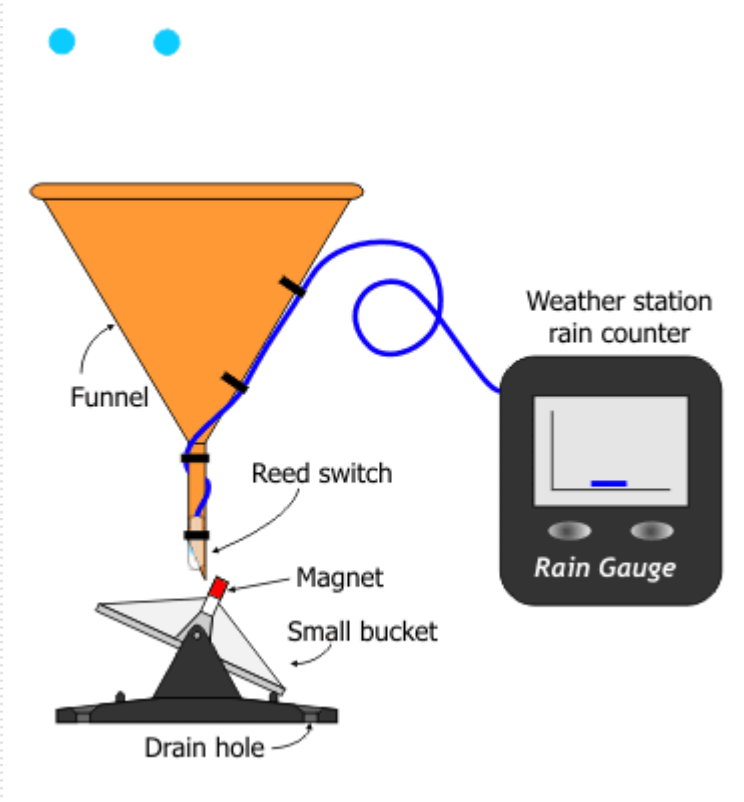
- **Tipping Bucket Rain Gauge**

# Rimco 7499 Tipping Bucket Rain Gauge (TBRG)

# Rimco 7499 Tipping Bucket Rain Gauge (TBRG)

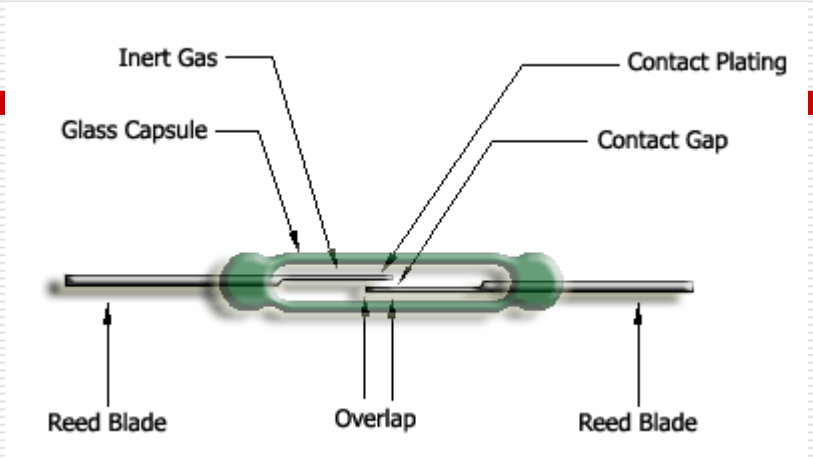


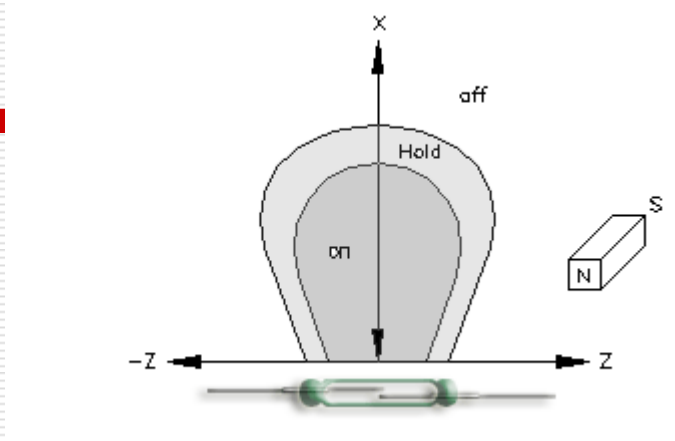
http://0.tqn.com/d/weather/1/0/w/0/-/-/Rain-gauge-animation.gif




Stephen

# The Reed Switch



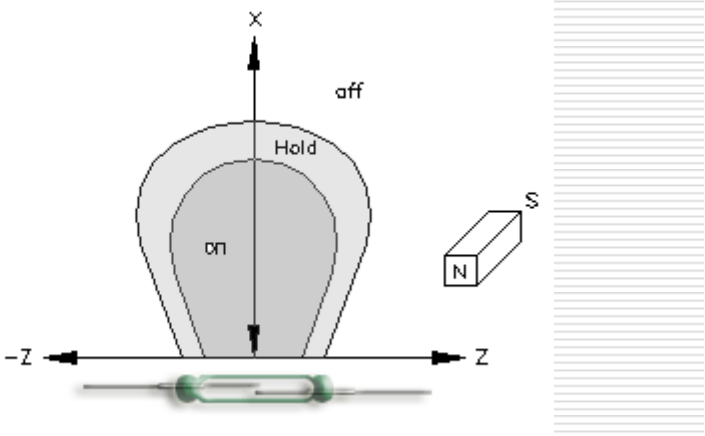




The output of a TBRG is a reed switch closure.

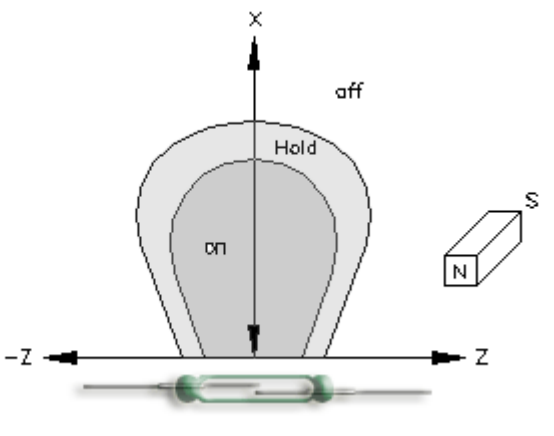
That is, the resistance of the TBRG outputs goes to zero.

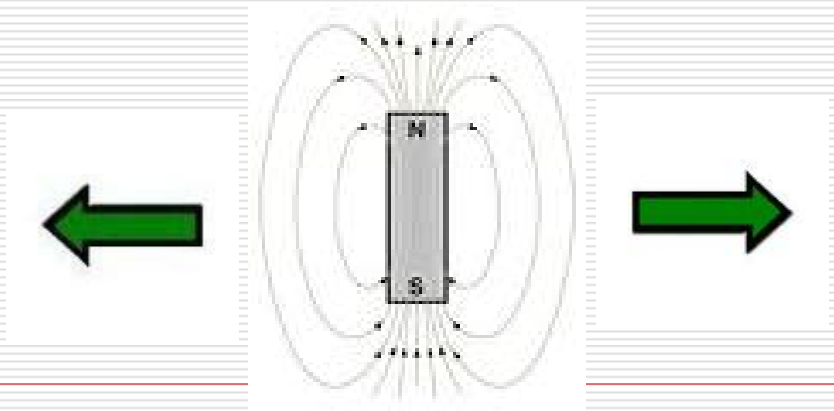
# Two Reed Switches

- Left Side



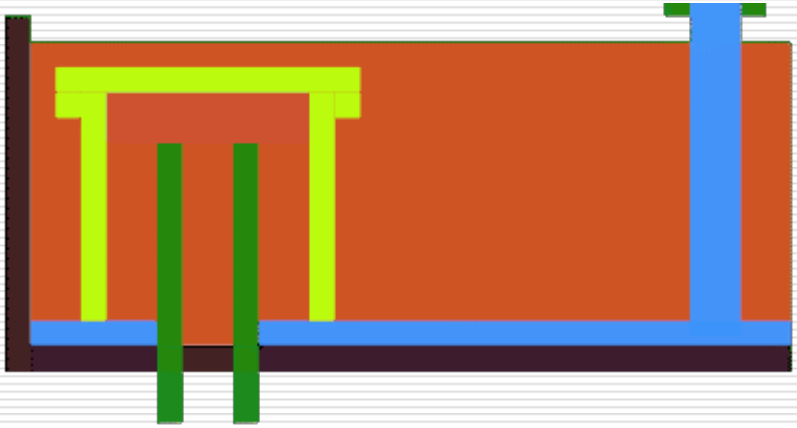

- Right Side



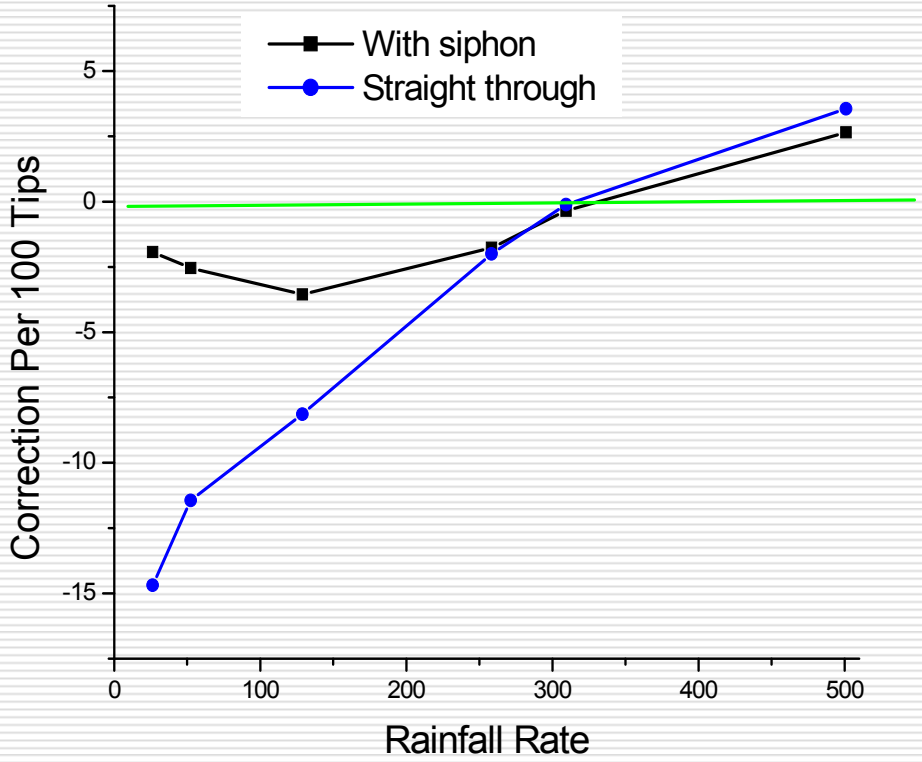
# The Siphon

- The siphon delivers a “constant” rainfall rate to the buckets
- This sets the momentum transferred to the buckets which would otherwise change as rainfall rate changed



# The Rimco 7499 TBRG

- The effect of removing the siphon from a TBRG will change rainfall totals measured by 10 to 15%.
- Adding a siphon makes the TBRG more “flatter” at low rainfall rates
- Once the siphon breaks down the two curves are equal.

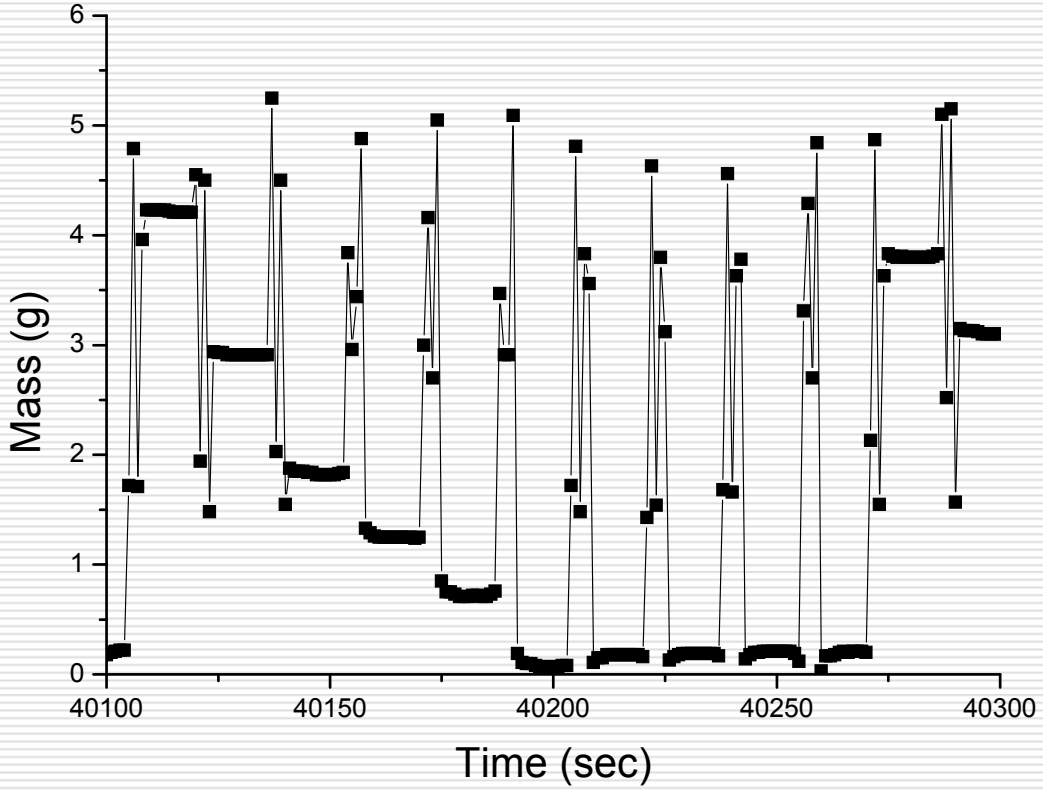


# Water Retained in the TBRG

- At the beginning of a TBRG test the amount of water within the gauge is unknown.
- The bucket may contain between 0 and 1 tip.
- The siphon may contain between 0 and 2 tips.
- Therefore the gauge may contain between 0 and 3 tips!
- The same is true at the end of the test.
- Therefore some of the water delivered by the field calibration device may not have led to a tip.

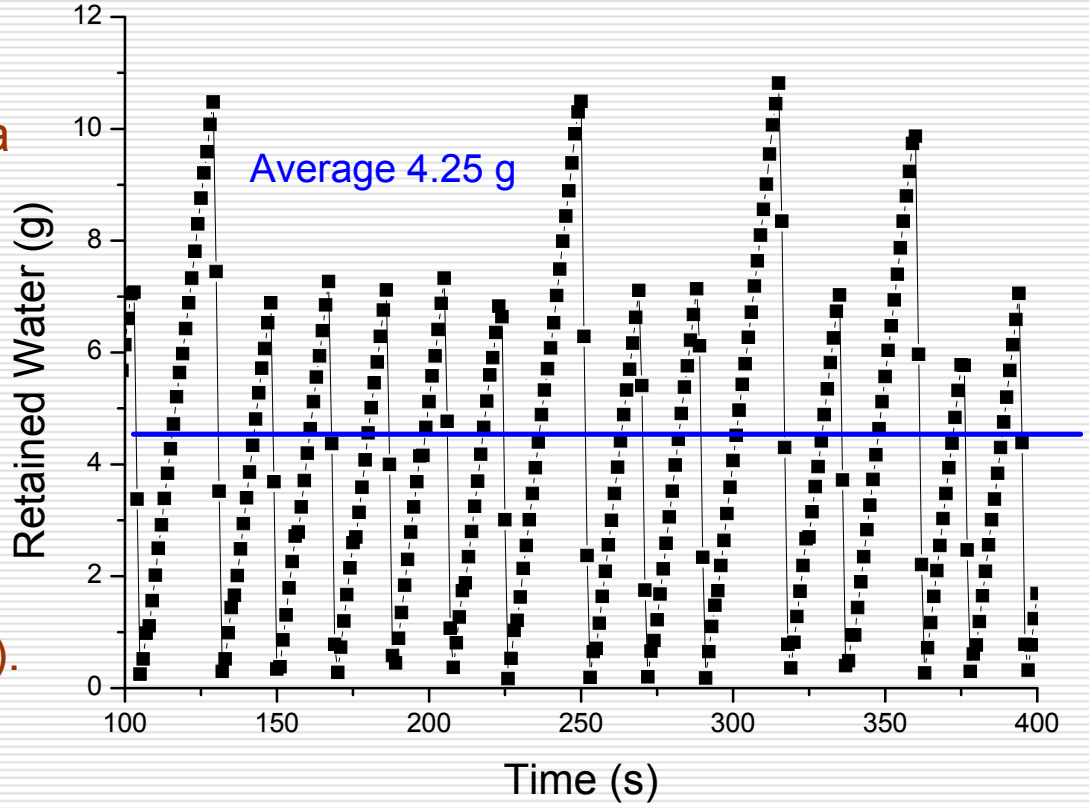
# Water retained in buckets versus time

Water retained in buckets versus time.
The gauge was subjected to a flow rate of approximately 100 mm/h.
Note the cyclical nature of the retained water.
The water sitting in the bucket while the siphon fills is the flat regions in the plot opposite.

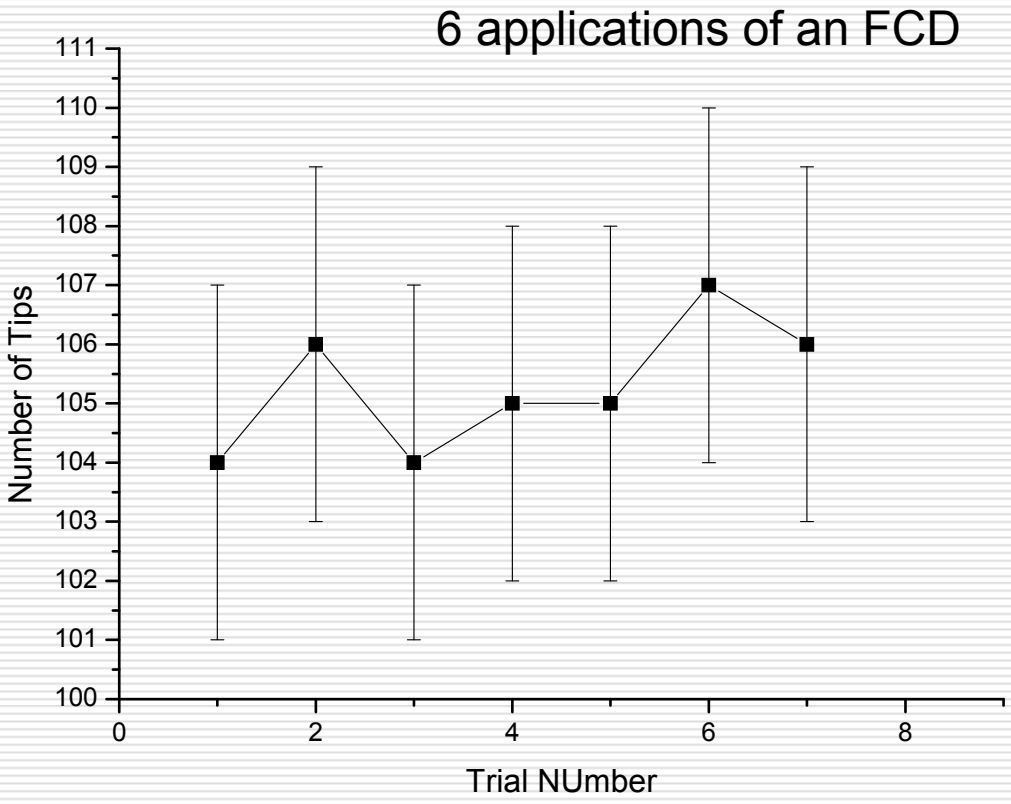


# Water retained in siphon versus time

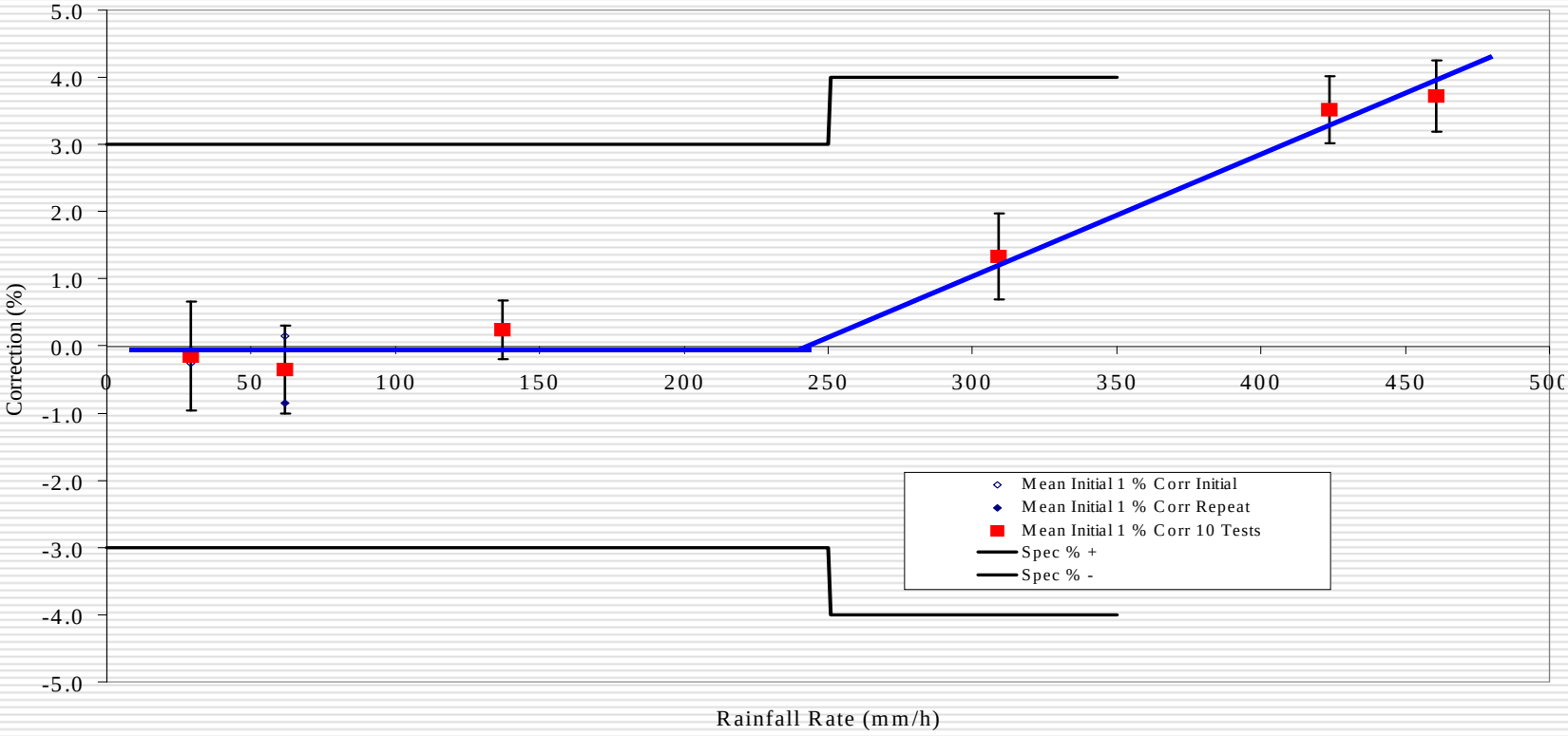
- When a constant stream of water was passed into a gauge the mass of water held in the buckets varied as shown opposite.
- Rainfall rate was approximately 100 mm/h.
- Note: sometimes it releases at approximately 1 tip (6.5 g) sometimes approximately 2 tips (13 g).
- The scales may not have captured the completely full part of the cycle.



# This leads to:



# Ideal Calibration Curve for a TBRG with Siphon




NB: Black lines are the BoM Specification A1980(4)

# TBRG Testing -10 Years Ago

- Gravity fed Boyle bottles
- Tests showed the variation was approximately ¼ of a tip.
- Lack of select ability of flow rate due to the limited number of nozzles (6) and their fixed size.
- Variability of flow rate due to nozzles becoming blocked with time.
- Variability of nozzle flow from run to run.

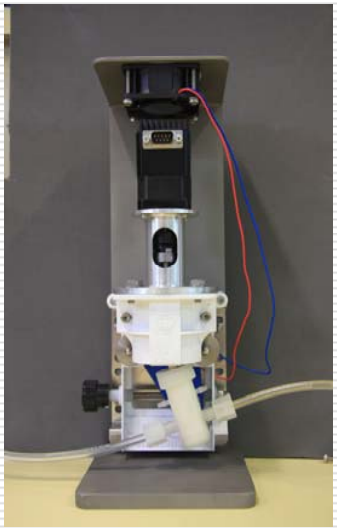
# 5 Years Ago - Peristaltic Pump

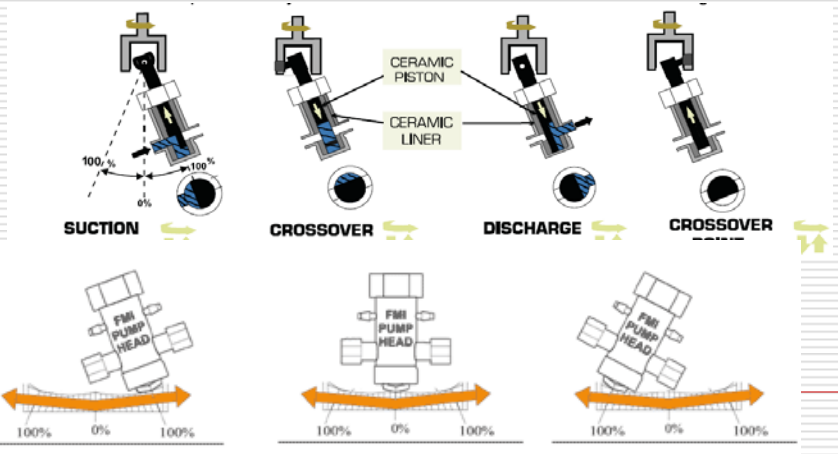

# Disadvantages

- Some drift in rainfall rate (approx. 0.5% per 24 hours of operation)
- Tubing needs regular replacement (once a week during continuous operation).
- Equipment of the systems is expensive, approx $15k each system.
- Minimum of 300 tips required to reduce biases in the ‘taring’method.

# Now ..... Pump-Stepper Motor System.

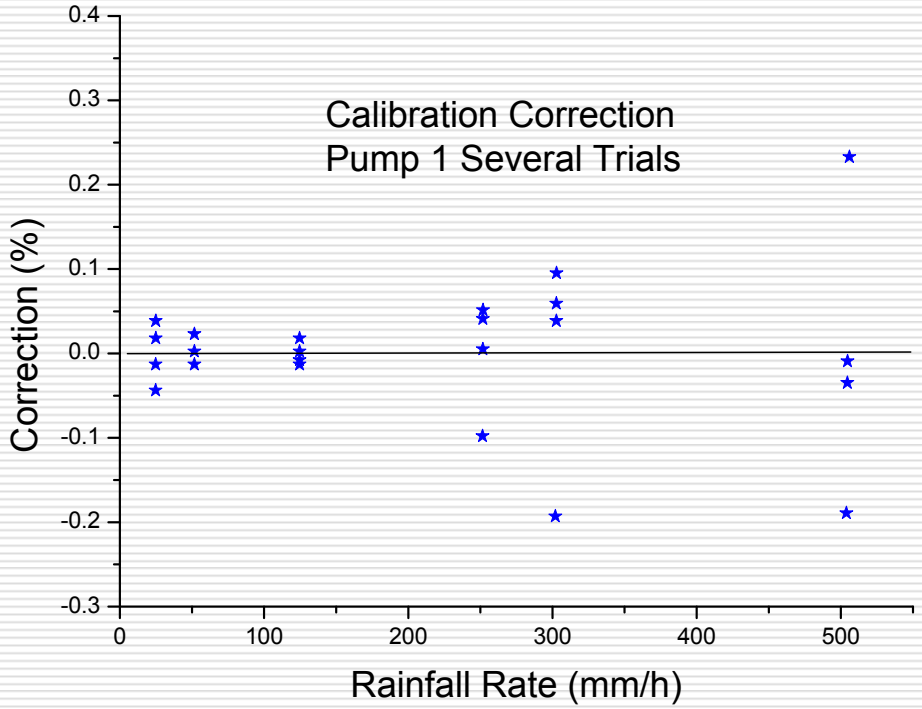
- extends range down to ≤ 2 mm.hr$^{-1}$
- High precision in RFI and tips



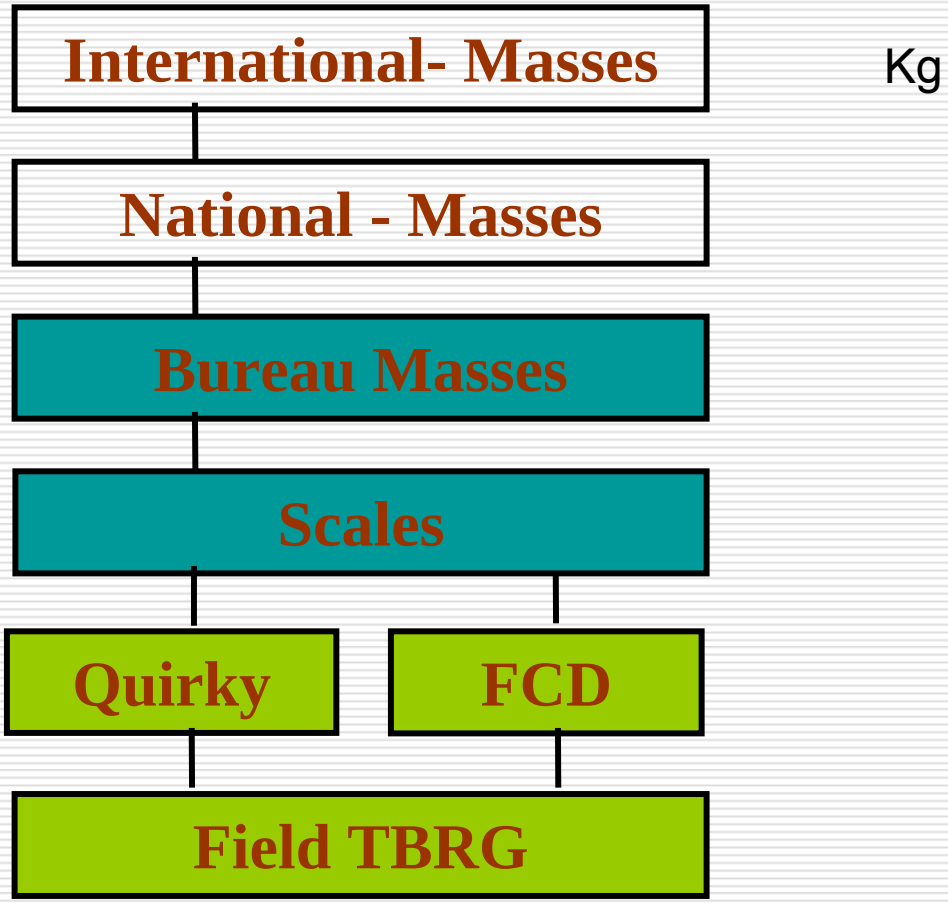


# Precision (Repeatability)

The repeatability of the pumps is a few parts per thousand

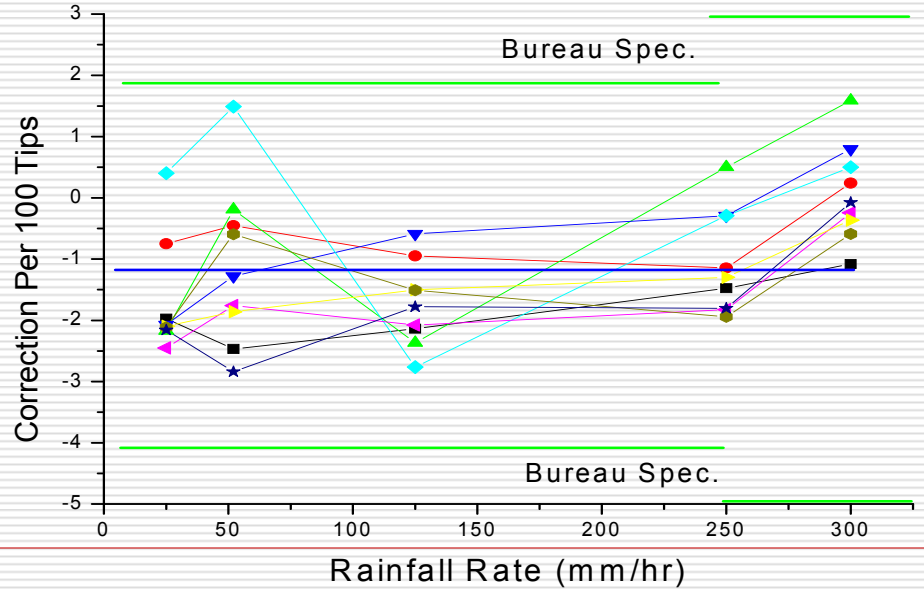


# Bureau Rainfall Traceability



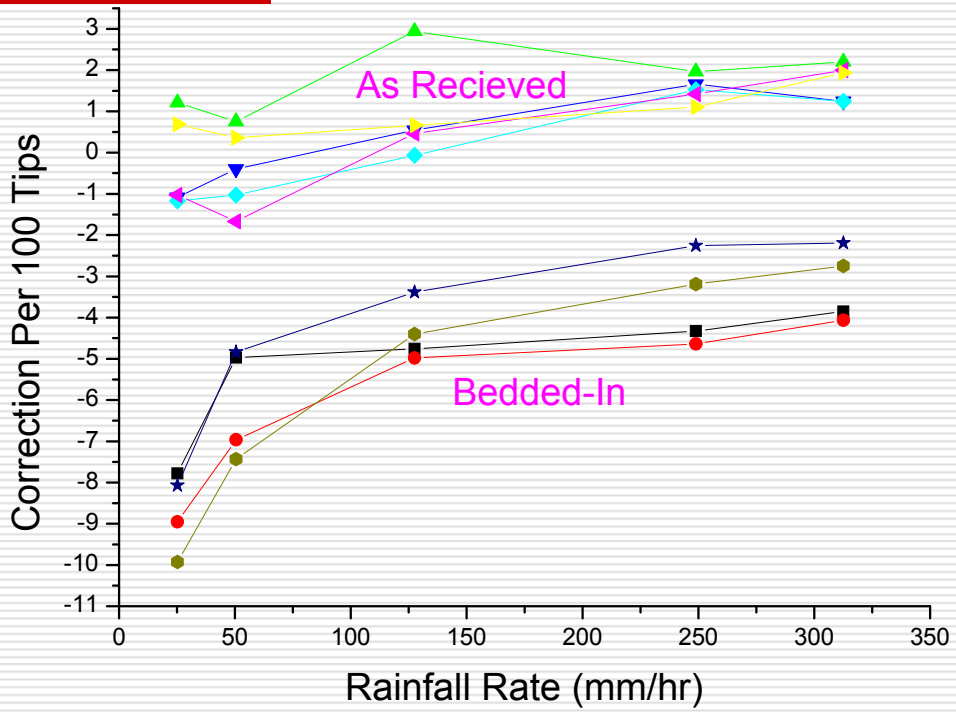
# Real TBRGs

- Rimco 7499 gauges ‘as received’ for testing
- Repeatability of new gauges is a few per cent
- Testing system is therefore about 10 times more repeatable than the gauge under test.



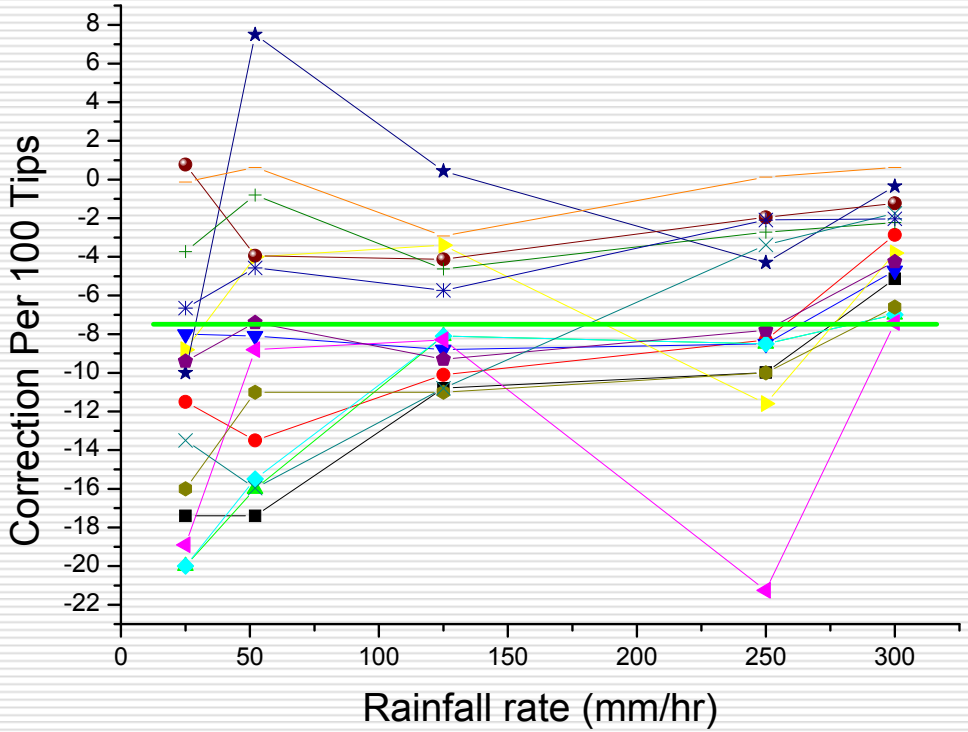
# Hydrological Services TBRG Testing (TB-3)

- HS gauges showed bedding in similar to the 7499 gauges.
- There appeared to be an increase in sensitivity at low rainfall rates after bedding in.



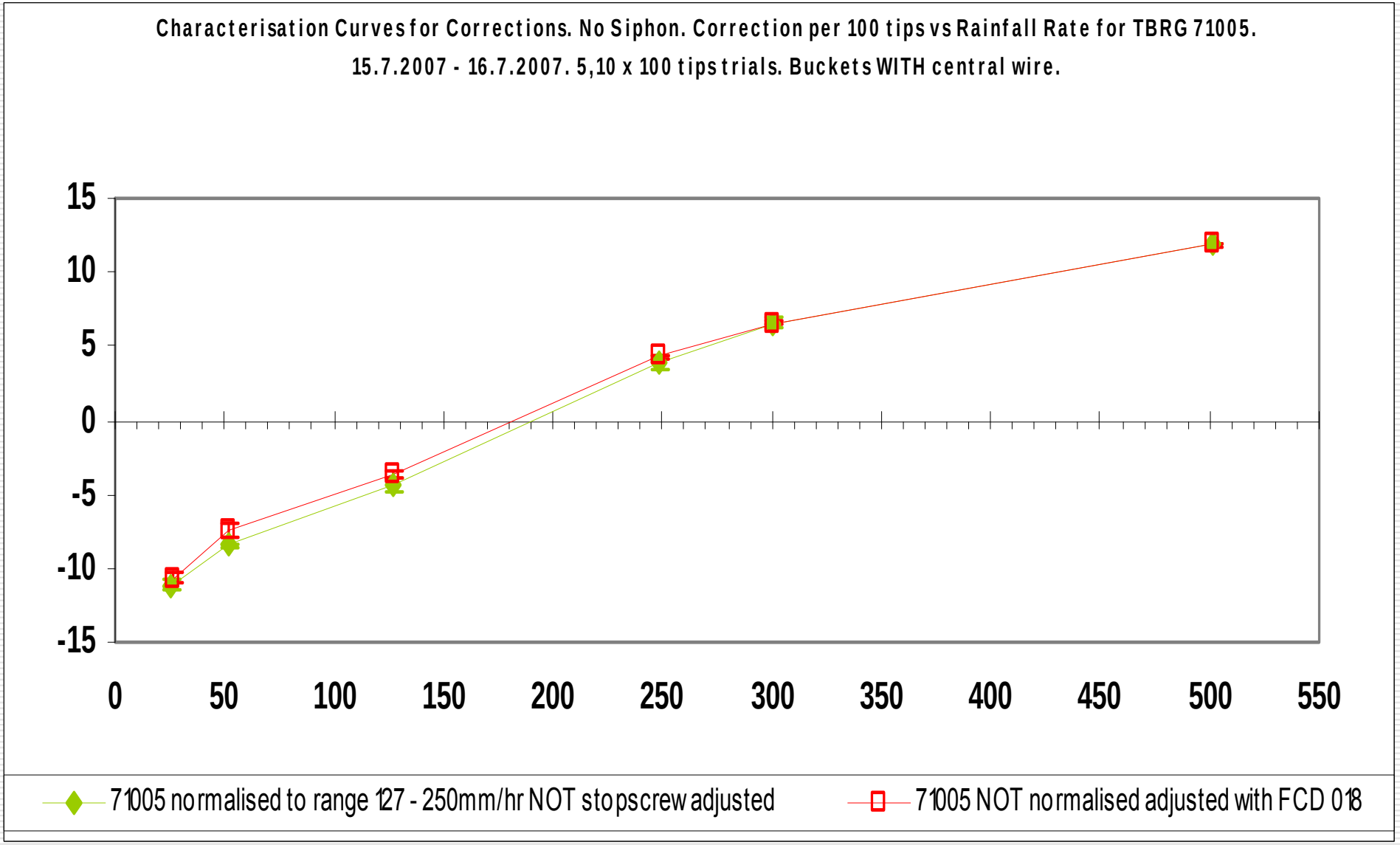
# Environdata TBRG testing (RG-15)

- Environdata TBRGs showed poor reproducibility



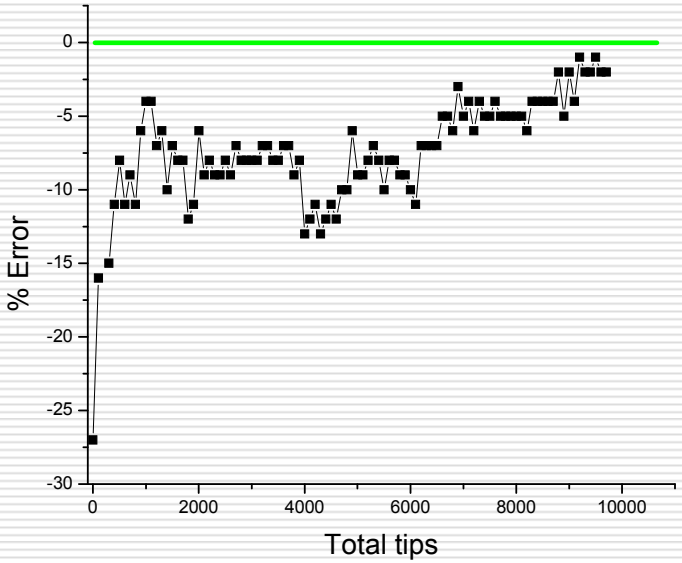
# Characterisation. No siphon.

Comparison of Normalisation vs Manual adjustment with stopscrew.



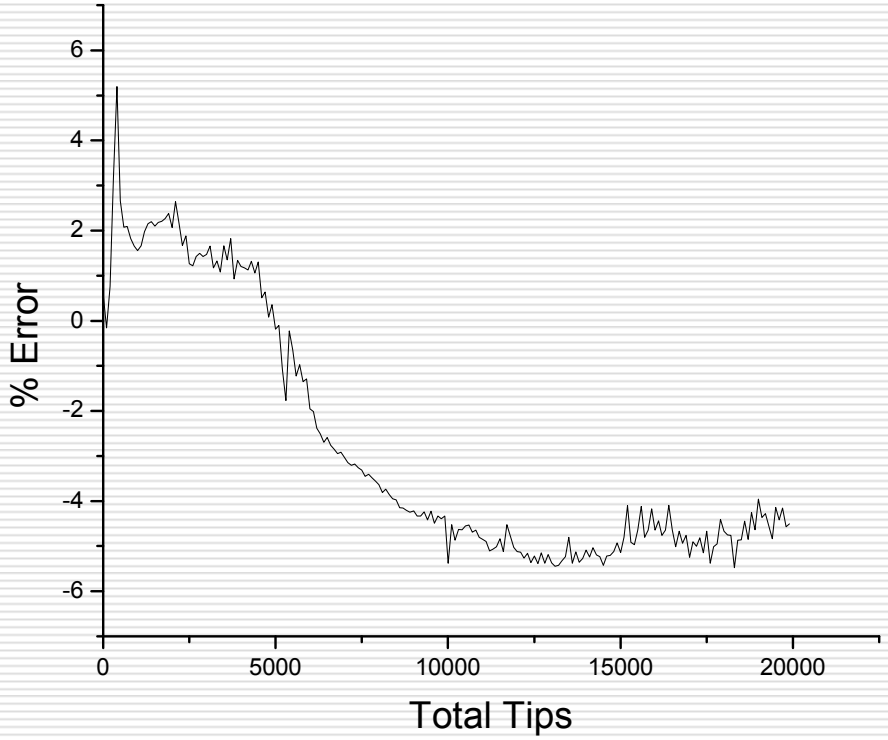
# Error and drift in gauge after ‘rough’ treatment.

- % Error for a 7499 gauge versus total number of tips through the gauge.
- The rough treatment included moderate shaking with the buckets free and moderate shaking while inverted with the buckets free.
- Large initial errors can be expected while the buckets settle-in.



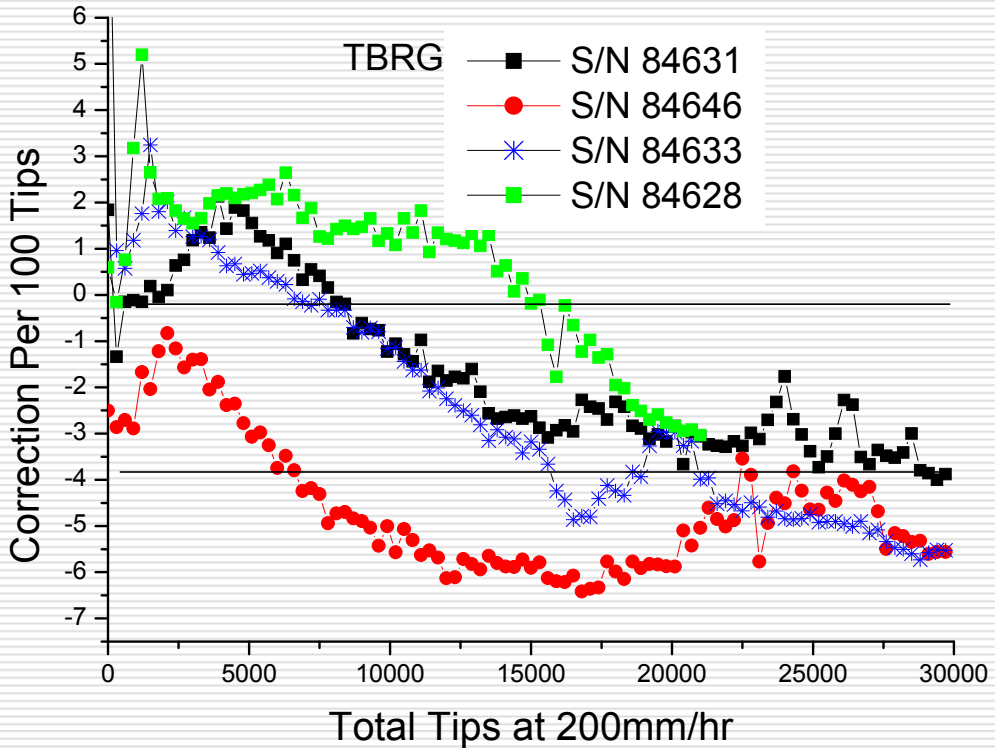
# Long term drift in a New TBRG

- Graph of the relative error of a 7499 TBRG repeatedly tested from new over a period of 5 days.
- The drift of approximately 3% during the ‘bedding-in’ process is typical of this type of gauge.
- Typically a gauge takes approximately 5000 tips to before it stops drifting; that is about 1 metre of rain!



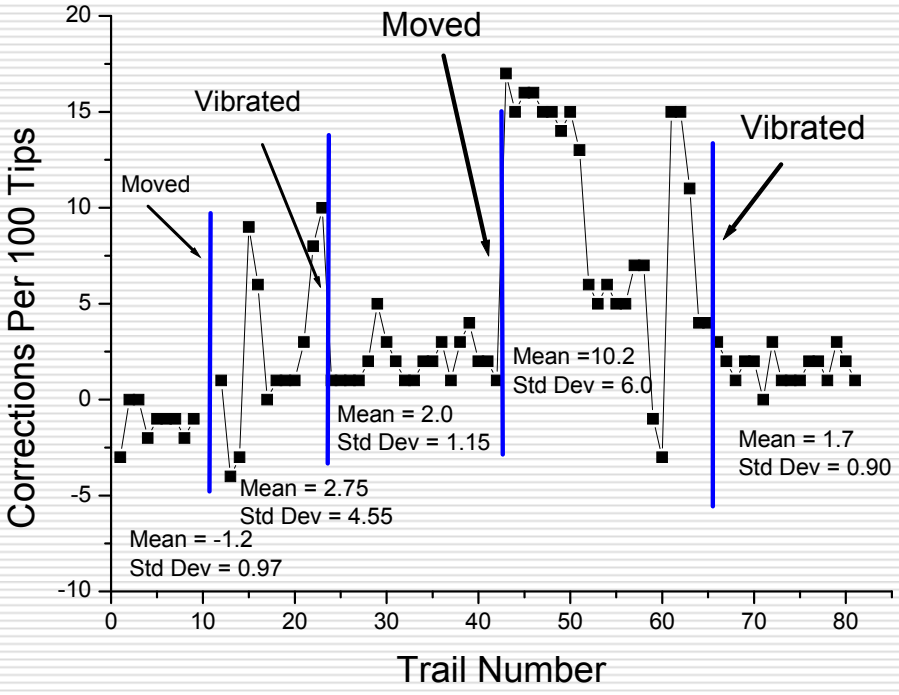
# Bedding-in of various new gauges

Opposite is the plots of 4 new 7499 gauges as they bed-in.



# Attempts at Rapid 'Bedding-in'

- Corrections required for a TBRG that has been subjected to a number of movements.
- This was to simulate transport and unpacking etc. To rapidly bed the gauge in it was vibrated while it was in position.
- The gauge was vibrated using an electric motor.
- It settles the gauge very quickly but is not practical in the field.



# Manual testing with HS Field Calibration Devices (FCD)

- Gauges are also tested manually using 200 mm.h$^{-1}$ FCDs (Volume ~ 654 ml).
- This is done because it:
- confirms the results of the automated testing;
- replicates the field calibration of the gauge;
- is quicker.

# TBRG Tolerance

| Sensor | Comparison Method | Uncertainty | Field Tolerance |
|---|---|---|---|
| **Rainfall TBRG with syphon** | **TBRG Calibration tool** | **3 % (<250mm/h) 4 % (>250mm/h)** | **6 % 6 %** |
| **Rainfall TBRG without syphon** | **TBRG Calibration tool** | **8 %** | **8 %** |

## FCDs (Volume ~ 654 ml)

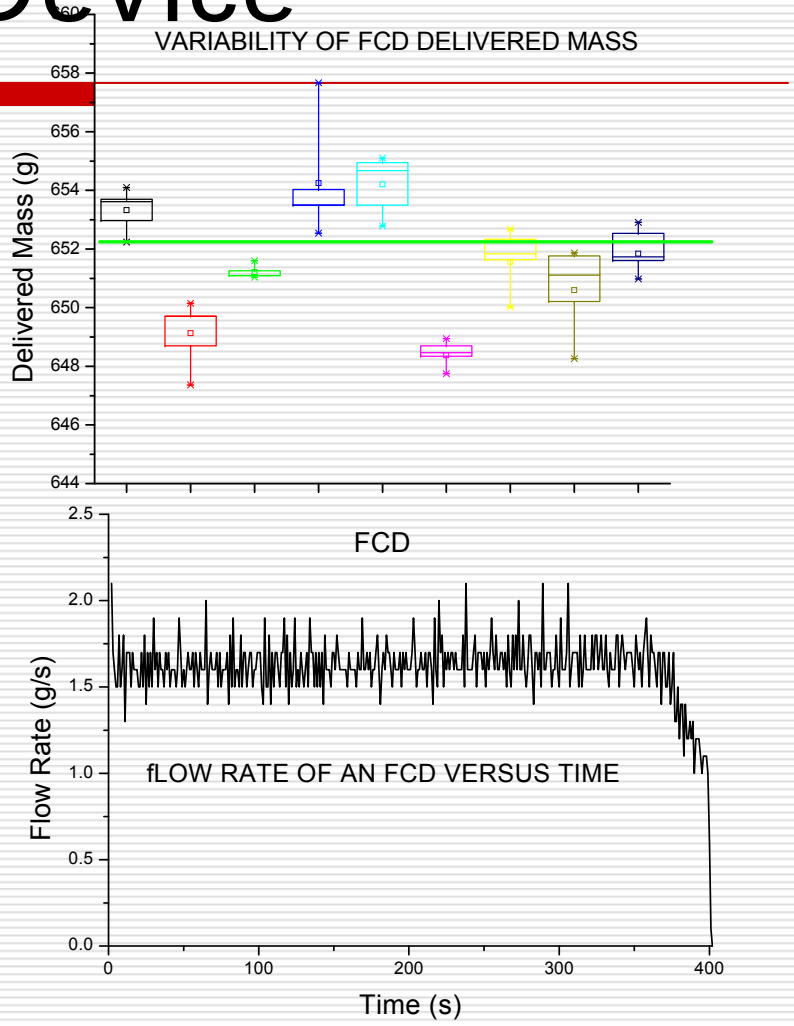
Rimco 7499 bucket volume: 6.473 ml
HS TB3 volume: 6.28 ml

654/(6.473) = 101.
654/(6.28) = 104.

**INSPECTION HANDBOOK CHAPTER 3.2 March 2008**

# The Hydrological Services Field Calibration Device

- the mass of water delivered.
- the time taken to empty;
- the repeatability of the FCD;
- the reproducibility of the FCD.
- The FCD delivers a volume of water, the TBRG is essentially a balance and tips on mass.
- Volume and mass are related via the temperature of water.
- Note the flow rate is essentially constant until the last 10 tips.



# Expected number of tips

## Expected number of tips including temperature and retained water effects

| Temperature (°C) | Expected tips |
|---|---|
| 4 | 300.9 |
| 20 | 300.4 |
| 40 | 298.5 |
| 60 | 295.98 |

# Effect of water temperature on the number of expected tips for three applications of the FCD.

| Temperature (°C) | Density ($kg/m^3$) | Correction (tips) |
|---|---|---|
| 4 | 999.99 | 0.0 |
| 20 | 998.23 | 0.5 |
| 40 | 992.25 | 2.4 |
| 60 | 983.89 | 4.9 |

**Example: TBRG in direct sun (Kimberley?), has been reported to be ~ 60 °C**

# Options for correction strategies

At least four options suggest themselves:

ignore the bias introduced by variations in water temperature and increase the uncertainty of rainfall measurement;

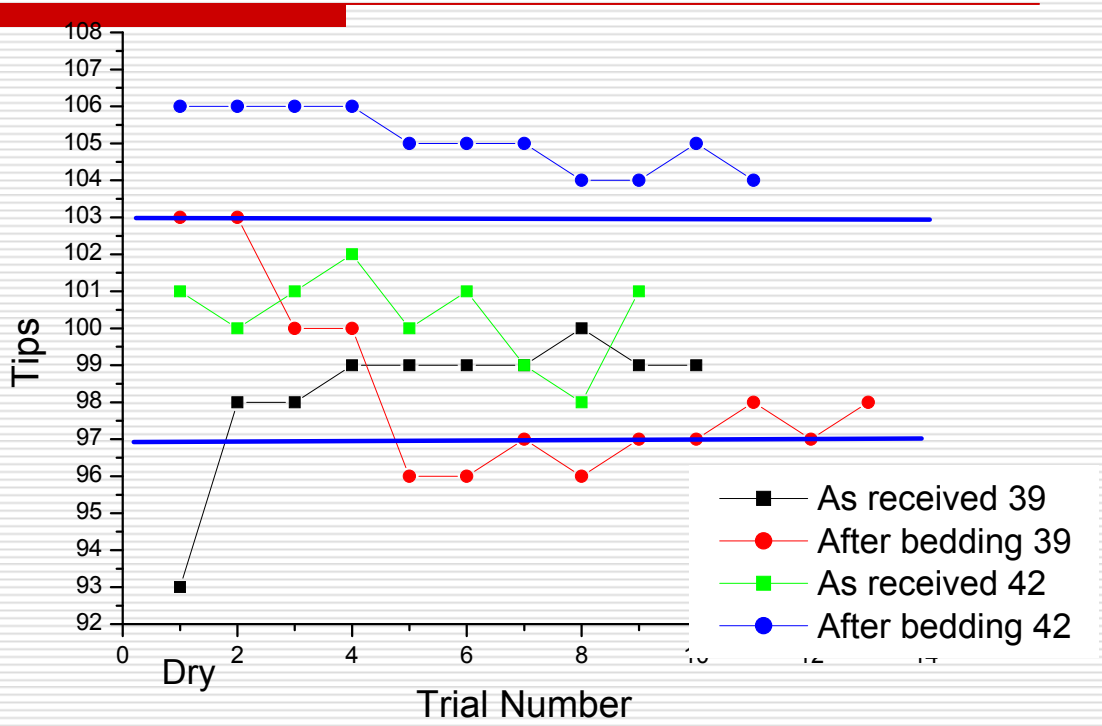
supply a correction table and measure the temperature of the water used in the FCD;

keep the water cool ( 20$^{o}$C);

apply a correction of 0 if the water temperature is below body temperature and +3 tips if the water temperature is above body temperature.

# Field testing with an FCD

Opposite is a plot of the number of tips recorded for repeated testing of 4 new TBRGs using the same FCD.
Two of the TBRGs take 4 or more applications before they settle in (red & black).
These gauges were set up according to the instructions in the surface obs handbook.



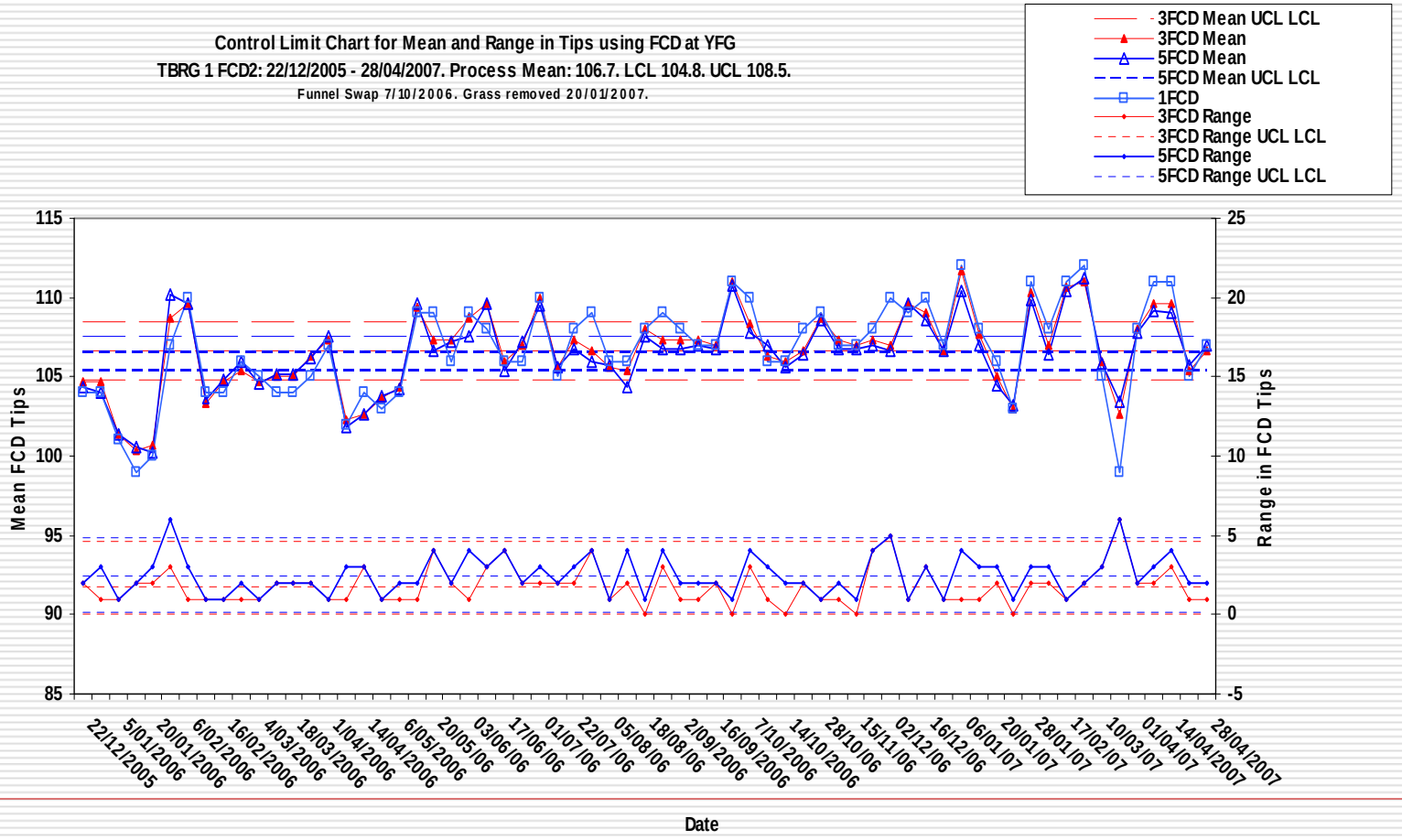
# TBRG performance w.r.t. FCD tests.

The following slides study TBRG performance at site YFG, with weekly tests of five applications of FCD on two TBRGs.

Data is graphed in the following X-bar/Range Charts. (X-bar = average. Range = max – min).
The charts need to be compared simultaneously; conclusions should relate to the overall structure of the X-bar and the Range charts.

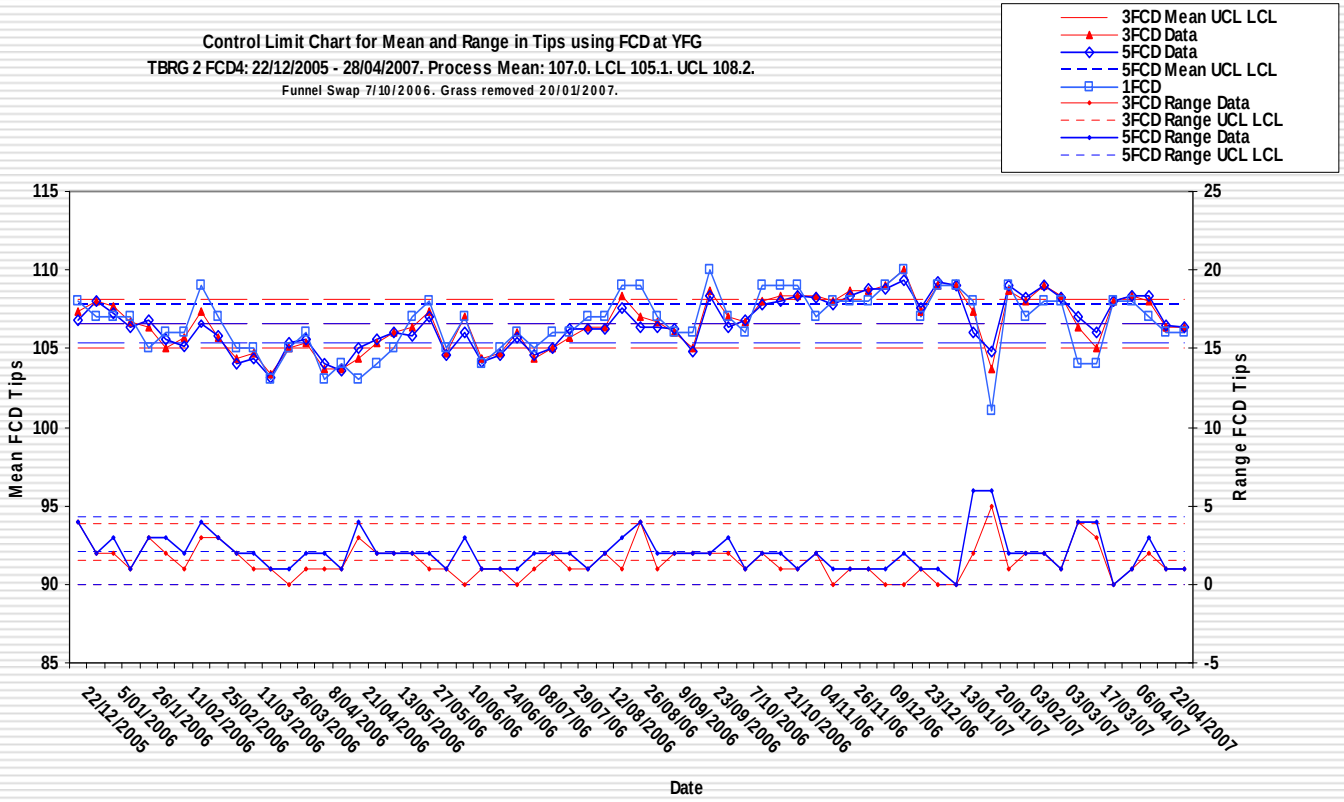
# Performance of TBRG 1, w.r.t. FCD tests.

(5 FCD ~ 3 FCD) Control Chart limits included.

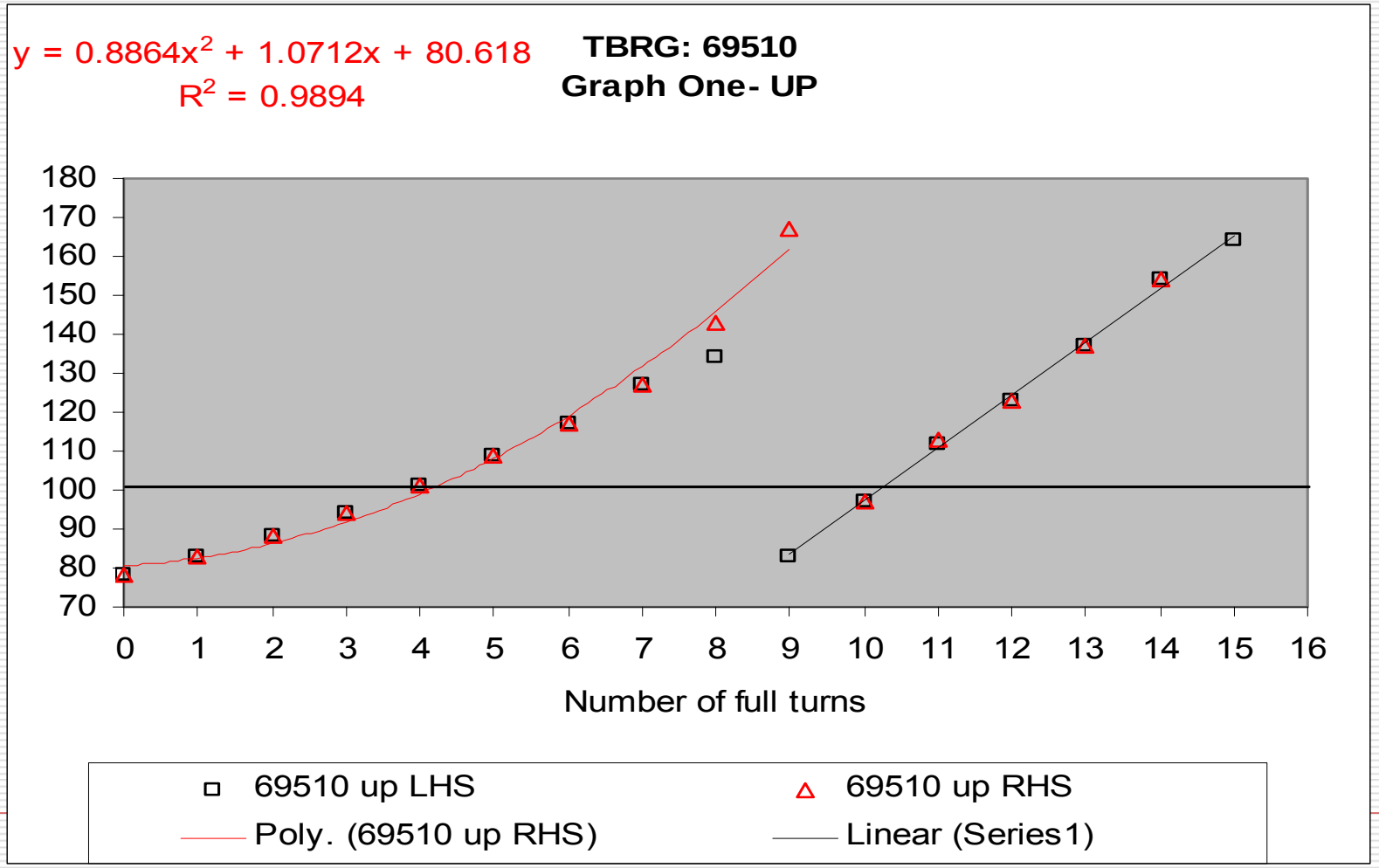


# Performance of TBRG 2, w.r.t. FCD tests.

(5 FCD ~ 3 FCD) Control Chart limits included.



# Effect of stop-screw adjustment for one 7499 TBRG



# Some points from the presentation.

•The BoM allows 3% to 4% variation for new TBRGs.
The long-term process standard deviations for TBRGs are also estimated to be 3 to 4 tips.Water temperature affects the water density in the FCD and the siphon; …allow the short-term test (“spot check”) with an FCD to be 6% (6 tips) for 101 tips;
When adjusting to 101 tips, the stop-screws should first be wound down to the assembly bed. This should minimise the time for adjustment.
There seems little difference between 3 or 5 applications of an FCD.
From an initial study, wind speed, wind gust, temperature and rainfall totals do not seem to affect the mechanical performance of the 7499 TBRG.
A possible “bedding-in” seems to apply to some 7499 TBRGs, estimated at a rate of about 2% per 1000 tips.

End

Questions???

# RIC Reports relating to TBRGs and FCDs

- ITR 679 - The Uncertainty of the HS Field Calibration Device (11/10/2004)
- ITR 675 - Laboratory Evaluation of the Bureau designed Heated Tipping Bucket Rain Gauge (15/10/2003)
- ITR 673 - Evaluation of the Environdata Precipitation Gauge Tipping Bucket Model RG-15 (27/2/2003)
- ITR 672 - Evaluation of the Rimco Precipitation Gauge Tipping Bucket Model 7499 (18/2/2003)
- ITR 671 - Evaluation of RIC Designed Pumped TBRG Tester [Rex] (1/9/2003)
- ITR 669 - Evaluation of the Hydrological Services Precipitation Gauge Tipping Bucket Type TB-3 (17/2/2003)
- ITR 660 - Stability of five McVann Model 7499 TBRG (22/8/2001)
- ITR 655 - Acceptance Tests of 20 Hydrological Services TB-3B Tipping Bucket Rain Gauges (17/9/1999)
- ITR 652 - Evaluation of a Tipping Bucket Rain Gauge Calibrator (13/1/2000)
  TN2004_005 - Testing of prototype Hydrological Services 1 mm FCD (29/11/2004)
- TN2004_004 - McVann RIMCO TBRGs 2004 (10/11/2004)
- TN2004_003 - McVann 7499 TBRGs 2004 (21/10/2004)
- TN2004_002 - Woodgate refurbished TBRGs (29/09/2004)