5. Evaluation of Uncertainty of the Drying Method

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Measurement procedure of the drying method

- 1: Prepare the samples of adjusted moisture.
- 2: Grind the samples in a grinder.
- 3: Measure the constant weight of the weighing can to be used.

  Repeat once.
- 4: Transfer the crushed samples into the weighing can and weigh them.

  Repeat once.

  Samples…Two samples are taken from the same lot.
- 4: Dry the samples.
- 5: Weigh the samples after drying.

  Repeat once.
- 6: Calculate the moisture content.

The source of uncertainty of the drying method

- Uncertainty caused by the **distribution of temperature** in the dryer.
- The uncertainty of this distribution is evaluated from the deviation between the samples' moisture content which are measured when the same samples are placed at **different regions**.

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The source of uncertainty of the drying method

- Uncertainties caused by the **repeatability** and the **deviation** between samples.
- This is calculated simultaneously from the above experiment.

The source of uncertainty of the drying method

- Uncertainty caused by the reproducibility of the **grinders**.
- Prepare the grinders, which is the **same type**. And evaluate the **deviation** between grinders.

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The source of uncertainty of the drying method

- Uncertainty in **mass measurement**.
  - Uncertainty of the mass of a weighing can.
  - Uncertainty of the mass of a weighing can and the samples.
  - Uncertainty in the calibration of a weighing machine.

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Model equation of the drying method

- Model equation

$$M = \frac{m_0 - m_1}{m_0 - m_c} \times 100 + e_T + e_R + e_G$$

M: The moisture content in the sample.
m_0: The mass of the sample before drying + the mass of the weighing can.
m_1: The mass of the sample after drying + the mass of the weighing can.
m_c: The mass of the weighing can.
e_T: Moisture dispersion caused by the distribution of temperature in the dryer.
e_R: Moisture dispersion caused by the repeatability and the deviation between the samples.
e_G: Moisture dispersion caused by the reproducibility of the grinders.

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Model equation of the drying method

- The law of propagation of uncertainty is applied in the above equation

$$\frac{\partial M}{\partial m_0} = \frac{100\left(m_1 - m_c\right)}{\left(m_0 - m_c\right)^2} \qquad \frac{\partial M}{\partial m_1} = -\frac{100}{m_0 - m_c} \qquad \frac{\partial M}{\partial m_c} = \frac{100\left(m_0 - m_1\right)}{\left(m_0 - m_c\right)^2}$$

$$u_c^2\left(M\right) = \left[\frac{100\left(m_1 - m_c\right)}{\left(m_0 - m_c\right)^2}\right]^2 u_{m0}^2 + \left[-\frac{100}{m_0 - m_c}\right]^2 u_{m1}^2 + \left[\frac{100\left(m_0 - m_1\right)}{\left(m_0 - m_c\right)^2}\right]^2 u_{mc}^2 + u_T^2 + u_R^2 + u_G^2$$

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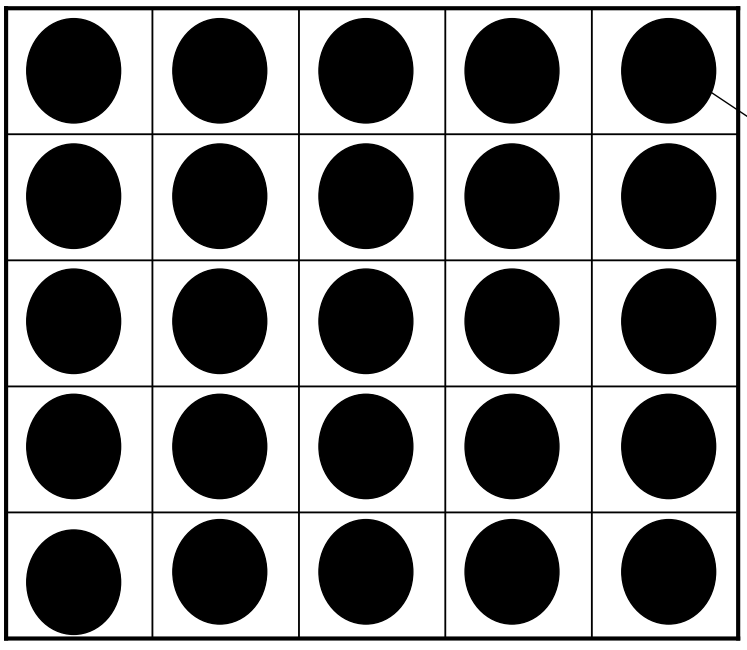
Evaluation of several standard uncertainty

- Uncertainty caused by the **distribution of temperature** in the dryer.
- The interior of the dryer is divided into **25 regions**. The moisture content of 25 samples that are sampled from the same lot and placed in several regions are measured. This measurement is **repeated twice**.

Uncertainty caused by the distribution of temperature in the dryer.



Weighing can with sample which derived from same lot.

The interior of the dryer

Uncertainty caused by the **distribution** of **temperature** in the dryer.

	n1	n2
P1	13.97	13.99
P2	13.89	13.98
P3	13.96	13.98
P4	13.89	13.92
P5	13.99	13.95
P6	13.97	13.98
P7	13.94	13.94
P8	13.97	13.96
P9	13.96	13.99
P10	13.91	13.97
P11	13.90	13.92
P12	13.98	13.99
P13	13.95	13.98
P14	13.98	13.93
P15	13.96	13.99
P16	13.97	13.98
P17	13.89	13.94
P18	13.97	13.97
P19	13.94	13.96
P20	13.90	13.96
P21	13.96	13.93
P22	13.99	13.97
P23	13.88	13.92
P24	13.92	13.97
P25	13.97	13.95

ANOVA*

Factor	Sum of square, S	Deg. free. f	Variance, V	Expectation of variance, $E(V)$
Place	0.03071200	24	0.00127967	$\sigma_e^2 + 2\sigma_P^2$
Error	0.01665000	25	0.00066600	σ_e^2
Total ST	0.04736200	49		

*ANOVA: **Analysis of variance** developed by Sir Ronald Aylmer Fisher

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Uncertainty caused by the **distribution of temperature** in the dryer.

- Therefore, in actual measurement, two samples taken from the same lot are measured and the result is calculated from the mean of the values as follows:

$$u_T = \frac{0.01752}{\sqrt{2}} = 0.01239 \ \%$$

σ_P

2 times repeat

Uncertainties caused by the repeatability and the deviation **between samples**.

- The variance of the error calculated in 1) represents the combination of repeatability and the deviation between the samples and the measurement result is calculated from the mean of the values as follows:

$$u_R = \frac{0.02581}{\sqrt{2}} = 0.01825 \ \%$$

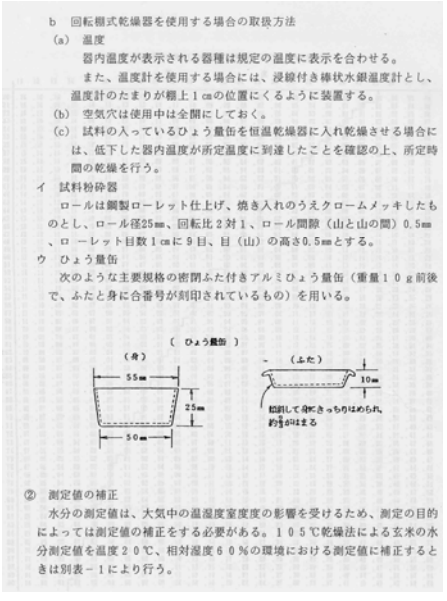
σ_e

2 times repeat

Uncertainty caused by the reproducibility of the **grinders**

Specification of the **grinder** is the one of the most influential factors to change the rice moisture in the drying method. Therefore, we recommend that specifications of the grinders are determined by several country standards.

Example: Japanese Standard



b　回転棚式乾燥器を使用する場合の取扱方法
(a)　温度
器内温度が表示される器種は規定の温度に表示を合わせる。
また、温度計を使用する場合には、浸線付き棒状水銀温度計とし、温度計のたまりが棚上1cmの位置にくるように装置する。
(b)　空気穴は使用中は全開にしておく。
(c)　試料の入っているひょう量缶を恒温乾燥器に入れ乾燥させる場合には、低下した器内温度が所定温度に到達したことを確認の上、所定時間の乾燥を行う。
イ　試料粉砕器
ロールは鋼製ローレット仕上げ、焼き入れのうえクロームメッキしたものとし、ロール径25mm、回転比2対1、ロール間隙（山と山の間）0.5mm、ローレット目数1cmに9目、目（山）の高さ0.5mmとする。
ウ　ひょう量缶
次のような主要規格の密閉ふた付きアルミひょう量缶（重量10g前後で、ふたと身に合番号が刻印されているもの）を用いる。

（ひょう量缶）

② 測定値の補正
水分の測定値は、大気中の温湿度室度度の影響を受けるため、測定の目的によっては測定値の補正をする必要がある。105℃乾燥法による玄米の水分測定値を温度20℃、相対湿度60%の環境における測定値に補正するときは別表－1により行う。

Uncertainty caused by the reproducibility of the **grinders**

Although, the specifications of the grinders are determined, there is an uncertainty caused by the **reproducibility** of the **grinders**.
The samples that are sampled from the same lot are crashed by the **13 grinders**, and the moistures are measured. This measurement is **repeated twice**.

Uncertainty caused by the reproducibility of the **grinders**

No.	Moisture(%)	Average(%)
21	13.906	
	13.912	13.91
16	13.783	
	13.789	13.79
20	13.820	
	13.827	13.82
17	13.977	
	13.973	13.98
22	13.911	
	13.907	13.91
14	13.895	
	13.907	13.90
11	13.951	
	13.903	13.93
12	13.895	
	13.867	13.88
18	13.788	
	13.810	13.80
15	13.780	
	13.806	13.79
13	13.947	
	13.918	13.93
23	14.011	
	13.925	13.97
19	13.816	
	13.860	13.84

ANOVA

Factors	S	f	V	$E(V)$
Reproducibility of the grinders	0.10355988	12	0.00862999	$\sigma_{e2}^2+2\sigma_G^2$
Error	0.00735825	13	0.00056602	σ_{e2}^2
Total	0.11091813	25		

Uncertainty caused by the reproducibility of the **grinders**

The following values are taken from the ANOVA table:

$$\hat{\sigma}_G = 0.06350\%$$

In actual measurement, only one grinder is used

$$u_G = \hat{\sigma}_G = 0.06350\%$$

Uncertainty caused by the **mass of a sample** before and after drying + the mass of a weighing can

- u_{m0} and u_{m1} are evaluated using a combination of u_S and u_{mr}.

$$u_{m0} = u_{m1} = \sqrt{u_S^2 + u_{mr}^2} = \sqrt{0.000025^2 + 0.0001080^2} = 0.0001109\,\mathrm{g}$$

Budget Sheet

Symbol	Source	Standard Uncertainty	Sensitivity Coefficient	Standard Uncertainty (%)
u_T	Uncertainty caused by the distribution of temperature in the dryer	0.01239 (%)	1	0.01239
u_R	Uncertainties caused by the repeatability and the deviation between samples	0.01825 (%)	1	0.01825
u_G	Uncertainty caused by the reproducibility of the grinders	0.06350 (%)	1	0.06350
u_{m0}	Uncertainty caused by the mass of a sample before drying + the mass of a weighing can	0.0001109 (g)	17.1715 (%/g)	0.001904
u_S	Uncertainty in the calibration of a weighing machine	0.000025 (g)		
u_{mr}	Uncertainty of the weighing can and samples	0.0001080 (g)		
u_{m1}	Uncertainty caused by the mass of a sample after drying + the mass of a weighing can	0.0001109 (g)	-19.9605 (%/g)	0.002214
u_S	Uncertainty in the calibration of a weighing machine	0.000025 (g)		
u_{mr}	Uncertainty of the weighing can and samples	0.0001080 (g)		
u_{mc}	uncertainty of the weighing can	0.0000629 (g)	2.78894 (%/g)	0.0001754
u_S	Uncertainty in the calibration of a weighing machine	0.000025 (g)		
u_{CAN}	Uncertainty of the weighing can	0.0000577 (g)		
		Combined Standard Uncertainty(%)		0.06729
		Expanded Uncertainty(%) (k =2)		0.13

Measurement Results

- The mass of sample A before drying + the mass of weighing can A…….15.8234 g
- The mass of sample B before drying + the mass of weighing can B…….15.9631 g
- The mass of weighing can A…….10.8135 g
- The mass of weighing can B…….11.2915 g
- The mass of sample A after drying + the mass of weighing can A…….15.1234 g
- The mass of sample B after drying + the mass of weighing can B…….15.3112 g
- The moisture content in sample A…….13.97%
- The moisture content in sample B…….13.95%
- Mean value of the samples…….13.96%
- The moisture content in the lot of the rice is:

$$M = 13.96(\%) \pm 0.13(\%) \quad (k = 2)$$