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A Comprehensive Format for Specifying and Reporting Controlled Environment Regimes

Introduction

"Recipes" are a key concept in the process control standard, ISA-S88.01-1995 (ISA, 1995). Industrial process control applications now provide recipe-based tools for defining, executing, simulating and analysing process performance. Recipes can also be used to deliver controlled environment (CE) regimes. Thus, a CE recipe is a named variable set (e.g., T_{AIR}, VPD, ψ_{soil}), with corresponding levels (i.e., required mean and precision) and time dependence.

Importantly, recipes focus directly on environmental variables only (i.e., parameters relevant to subject processes- ψ_{soil}, R:FR ratio), and not how they are achieved (e.g., irrigation frequency, lamp rig make-up). This follows from the distinction between *recipes* (specified conditions), *regimes* (delivered conditions), and *equipment control* (details of which may vary between facilities or projects). This separation relies on control system algorithms to relate one to the others, improving flexibility and maintainability: i). by being able to deliver different regimes by altering recipe values; and ii). by allowing changes in control equipment without altering recipes (Nowicki, 1999).

A CE recipe format

A flexible recipe format has been developed at NZCEL. It features: i). integrated specification of environmental variables; ii). database compatibility for information management; iii). specification of statistical performance reporting parameters. It allows:

- Definition of constant and cyclic regimes
- Piecewise (e.g., meteorological data) and continuous functions (e.g., $T = f(t)$)
- Different ramp types (e.g., linear, cosine, exponential)
- Variable interaction (e.g., $T = f(\text{VPD})$
- Statistical performance reporting (mean, precision and sampling regime)
- Management by relational database applications
- Automated processing for operation and analysis

The format is table-based, consisting of records with 13 fields (Table 1). It is intended to be compatible with ICASA standards for experimental data files (Hunt et al., 2000), particularly in the use of variable naming conventions. (The ICASA standards are designed to facilitate documentation and data exchange for crop model development). Recipes may be specific to a CE project, or general (e.g., those used for routine calibration checking and post-project disinfestation), or a combination of both. In the last case, a recipe could include both individual project specifications, along with start-up, test, clean-up and shut-down conditions.

Table 1

Recipe field	Description
Recipe name	text string
Env. variable name	text (ICASA name preferred)
Unit	text string (SI units preferred)
Section name	text string
Section step delay	hours (from start date, local standard time)
Section step level	numeric value (or text-based math function)
Section cycles	numeric value > 0 (default = 1)
Section period	hours (default = max. step delay in section)
Ramp type to achieve level	linear, cosine, exponential (default = linear)
Ramp duration	hours (default = step duration, 0 = instant)
Sampling interval	hours (measurement frequency)
Reporting duration	hours (period over which samples averaged)
Required precision	numeric value (as std error of mean).

CE recipe examples

The flexibility of the format is such that recipes for static, cyclic and non-repeating regimes CE can be represented (Table 2), This common format will assist design and communication of CE specifications, especially complex time-series, by permitting their management within a single, simple data structure.

Table 2.

Recipe	EnvVar	Section	Delay	Level	Unit	Cycles	Period	Ramp
Fig. 1	WVPD	20hr@-0.2	0:00:00	-0.2	kPa		20:00:00	
Fig. 1	WVPD	15hr@-0.5	0:00:00	-0.5	kPa		15:00:00	
Fig. 1	WVPD	50hr@-0.3	0:00:00	-0.3	kPa	5	10:00:00	
Fig. 2	PPFD	Clouds	0:00:00	0	µmol/m2/s	2	40:00:00	
Fig. 2	PPFD	Clouds	6:57:00	0	µmol/m2/s			
Fig. 2	PPFD	Clouds	9:30:05	950	µmol/m2/s			
Fig. 2	PPFD	Clouds	10:25:20	560	µmol/m2/s			
Fig. 2	PPFD	Clouds	11:15:09	1308	µmol/m2/s			
Fig. 2	PPFD	Clouds	12:30:12	404	µmol/m2/s			
Fig. 2	PPFD	Clouds	14:03:21	910	µmol/m2/s			
Fig. 2	PPFD	Clouds	19:03:21	0	µmol/m2/s			
Fig. 3	TDRY	PN85Met.dat	0:00:00	20	°C			cos
Fig. 3	TDRY	PN85Met.dat	6:30:00	9.2	°C			cos
Fig. 3	TDRY	PN85Met.dat	14:00:00	19	°C			cos
Fig. 3	TDRY	PN85Met.dat	30:30:00	14.7	°C			cos
Fig. 3	TDRY	PN85Met.dat	38:00:00	21.8	°C			cos
Fig. 3	TDRY	PN85Met.dat	54:30:00	11.9	°C			cos
Fig. 3	TDRY	PN85Met.dat	62:00:00	25.1	°C			cos
Fig. 3	TDRY	PN85Met.dat	78:30:00	14	°C			cos
Fig. 3	TDRY	PN85Met.dat	86:00:00	20	°C			cos
Fig. 4	TDRY	SystemTest	0:00:00	20	°C	3	24:00:00	exp
Fig. 4	TDRY	SystemTest	5:00:00	12	°C			exp
Fig. 4	TDRY	SystemTest	10:00:00	30	°C			exp
Fig. 4	TDRY	SystemTest	15:00:00	18	°C			exp
Fig. 4	TDRY	SystemTest	20:00:00	40	°C			exp
Fig. 4	TDRY	SetUp	0:00:00	20	°C			
Fig. 4	TDRY	SetUp	22:00:00	20	°C			
Fig. 4	TDRY	SetUp	24:00:00	35	°C			
Fig. 4	TDRY	CyclicBit	0:00:00	35	°C	10	24:00:00	
Fig. 4	TDRY	CyclicBit	16:00:00	15	°C			
Fig. 4	TDRY	CleanUp	0:00:00	20	°C		24:00:00	
Fig. 4	TDRY	DisInfest	0:00:00	45	°C		72:00:00	

Figure 1.

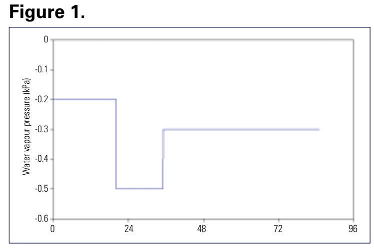


Figure 2.

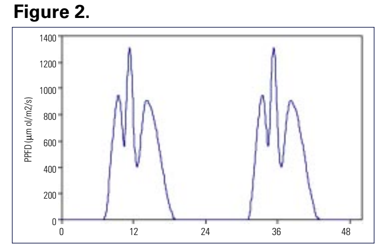


Figure 3.

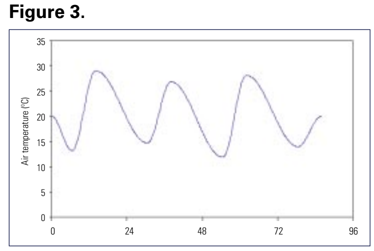
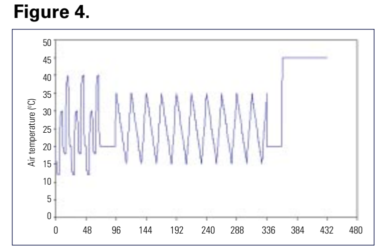


Figure 4.



References

Hunt, L.A., G. Hoogenboom, J.W. Jones, and J. White. 2000. ICASA files for experimental and modelling wok [Online]. Available by International Consortium for Agricultural Systems Applications http://www.icasanet.org/standards/index.html (posted April 14, 2000; verified July 2001).

ISA 1995. ANSI/ISA-88.01-1995 - Batch Control Part 1: Models and Terminology, pp. 1-98. ISA, Research Triangle Park, NC.

Nowicki, P.L. 1999. An ISA S88 equipment interface? [Online]. Available by World Batch Forum http://www.wbf.org/Publications/Nowicki%20S88.htm (posted Tuesday, 9 January 2001; verified July 2001).