O'Connell, Joseph, Metrology: The Creation of Universality by the Circulation of Particulars, *Social Studies of Science*, 23(1) (Feb. 1993), 129-173.[1]

Mots-Clés/Keywords (Mots-clés standardisés (voir banque de données))

Stratégies expérimentales; sciences en general; techniques et technologies; aspects tacites; robustesse; calibration; SHS

Domaine Objet/Domain & Topic

Physics and medicine (through the issue of measurement and devices therefore and the circulation and validation of facts acquired through measurement in these disciplines), metrology, standards and norms (social, cultural, informal, legal), instrumentation and technologies towards the production of accurate results in the sciences (esp. in connection with military usage and the US National Bureau of Standards)

Résumé/Summary

The paper is centred on the issue about how the universality of technoscience becomes achieved – taking the assumption that it is not a straightforward issue – in relation with how the circulation of particular 'objects' (here people, artefacts, documents, devices, ethereal norms) contributes to make them mean the same reality in distant locations, through, despite resistances against this process. In the paper, three examples are expanded about. One is that of the making and development of machines and devices to measure body composition, with a special emphasis on fat ("Body Composition"). The two other examples, which constitute the bulk of the paper and closely interlinked with one another, are concerned with electrical standards. One is an example exploring the international standardisation of electrical units in the late 19th century ("The Social History of Electrical Units"). The other is an example exploring the influence of the US Department of Defence on metrological activities in the US (again here examples and specifics are extracted from the history and sociology of electrical units) ("The Development of Intrinsic Standards," "The Problem of Authority" and "Calibration, Traceability, and the Power of Paper"). To these cases studies, the author adds concluding comments ("The Creation of Universality"), extensive notes, and an appendix, "Traceability Chart: Derivation of Electrical Units".

Thèses, Organisation de l'Article/Thesis & Argument, Narrative Organisation

Throughout the paper develops a thorough science studies case study analysis of metrological practices in relation to the emergence of accepted norms and standards, drawing, for its analytical approach, from some help by B. Latour, M. N. Wise for the treatment of the examples.

In the introduction (129-130), O'Connell expands, on the one hand, on how we commonly believe and "assume (correctly)" on the accuracy of results coming out of measurement systems and on how such assumptions and faith are "justified for the uses to which we put them", contrasting this, on the other hand, with how such

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accuracy is not straightforward, results from "enormous efforts" expanded towards this aim, and contributes to the "construction *of*" modern societies and of technoscience. Taking on from Fleck's notion of 'thought collectives' [Fleck's concept of 'Denkkollektiv'], he proposes the concept of '*material collectives*', original emphasis, "communities of persons and institutions mutually exchanging the same representations and material representatives for abstract scientific entities" (130) and explains his intent to explore the ways such collectives are formed, their motives, how this formation is resisted and how the authority of the standard representations emerges and is stabilised.

The first example is devoted to devices for the measurement of body composition, that is, the measurement of bodily compositions in relation with their various components (bones, fatty tissues...). The author expands on various episodes related to body composition measurement (dissection, organised and systematic dissection of dead bodies and formulation of modelling mathematical algorithms (1902-1950), towards hydrostatic weighing as an experimental method to obtain data towards algorithmic extraction of body composition). He particularly expands on hydrostatic weighing and how its popularisation among a growing population of weight-conscious people had led to (1) a further popularisation of the technique – measurement through a costly and subtle "troublesome" procedure involving getting soaking wet – and, later, (2) a rise of interest for potential alternative techniques which could allow to measure body composition without the cost and the disagreement of getting wet (131). The remaining of the section expands on how, in the 1980s, two US companies, *Futrex Inc.* and *Valhalla Scientific*, adapted research initially developed on agricultural products to human body composition measurement, producing easily, cheaper, portable instruments to measure fat proportion in human bodies, respectively the FUTREX-5000 and the 1990B Body Composition Analyser. Promoting these devices, both of which combined the use of bioresistance measurements then interpreted through computerised algorithms, was played out similarly by the companies: relations to funded research, rhetorical explanation by scientifically trained reps, reference to scientific papers... all strategies pointing out to how much their techniques could be legitimately understood as equivalent to hydrostatic weighing through claims of how accurate results were as compared to those by hydrostatic weighing, here 2%, here less... etc. Other debates in the promotional campaigns turned around issues of practical usefulness and easiness of use, many arguments and counter-arguments pointed out at "data collected so far" and their "collective value" (133). This, in O'Connell's argument, leads to a discussion about collectives' shifts, from one trusting hydrostatic weighing to one trusting artificial devices as the FUTREX-5000 and the 1990B. So as to ensure gaining this trust and the corresponding market niche, *Futrex* and *Valhalla* developed testing and standardising protocols and procedures, that gradually led to a degree of automation such as that "accuracy depends upon the skill with which the [measuring] machines [and corresponding algorithms] have been designed, rather than on the skill of the human user" (135). O'Connell then comments on how *Valhalla* explained this evolution and the related accuracy of these devices by the many circulations and travels of the people in many contexts so as to implement algorithms and measurement procedures as best as possible, which in the same time led to a limited development of alternative, more accurate techniques, however problematically more expensive and less straightforward to implement. With trust in the devices becoming acquired, further circulation of ever more trusted measurements becomes possible, leading to the stabilisation of the new 'bioresistance-algorithms' collective (135-136).

In the second example developed (p. 136-151), O'Connell proposes a historical and social account of the emergence of the current system of standardised units for the measurement of electrical phenomena (Ohm, volt, ampere). This account tells the story of the international standardisation of electrical units in the late 19th century,

from a social point of view emphasising here the forging of the electrical unit system through social interaction and a pondering through taking into account prestige, industrial and scientific benefits and losses at stake; typically this account tells about the conflict between the British Association for the Advancement of Science, promoting the ohm as a pure 'true to nature' standard, against the late 19th–century German industrial world which promoted the Siemens, a standard lesser close to natural truths but more easily humanly exploitable,[2]

and from a more Latour- and Fleck-inspired standpoint emphasising instead on how as the debates raged on, the arguments on units being or not as close as possible to their pure natural truth started to fade out due to the emergence of a community of metrologists or assimilated practitioners looking out for a unit system that would be both true to nature *and* useful and practical in the field, in the laboratory, that is, most importantly transportable without problematic impact on the stability of the standardising value of the unit.

In this narrative, O'Connell emphasises how the two standpoints – should the standard unit be close to Nature or practical? – although mutually exclusive in theory, ended up in cohabiting peacefully with standards being defined so as to be close to their natural ideal, and, in practice, represented, implemented using the techniques developed to make an easy transportable unit (142-147). Still the debates re-emerged as to what counts as a good standard unit as soon as procedures and institutions instituted the chosen standards. Indeed, standards, though travelling quite well, were not to be used to often to recalibrate equipment and disseminate: at too much use, they wore out, up to the point of no longer representing the true nature they were supposed to. Also one context or another might require another more suitable representative physical artefact, or one more independent from a specific factor embedded in a piece of equipment (147-152). As with the case of the body composition measuring devices, the practical solution followed on by users was again that of standards less accurate, but "less expensive and [that] can move around more readily than the primary standards from which they derive their accuracy" (152).

In the three next sections - "The Development of Intrinsic Standards" (152-157), "The Problem of Authority" (157-159), and "Calibration, Traceability, and the Power of Paper" (159-162) –, O'Connell turns his attention to his 3rd example, that of the development, dissemination and enforcement of intrinsic standards by the National Bureau of Standards (NBS) (in a later stage the National Institute for Standards and Technology (NIST)).

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[2] Mostly on pp. 137-147. A similar account can also be found in works and papers by Simon Schaffer mentioned in comments added to this summary. Schaffer tends to emphasise the social aspects in this story, pointing out in a more marked way to how this debate on electrical units located itself in a time of nationalistic rivalry between the UK and Germany as regards to their emerging electrical manufacturing industry.

This example, which draws on the second example developed in the paper, first expands on how the NBS and the NIST, partly under impulse and assisted by the US Department of Defence, contribute to disseminate standards through (1) the maintenance of 'artefact standards', that is, traceable artefacts representing a said recognised and praised 'true' standard, and (2) the development of 'intrinsic standards', that is, physics experiments reproducible in various locations that permit the local reproduction of standards "to the highest accuracy that is legally recognised" (153). Again, despite appearances suggesting a wish to stay close to achieving the stamp of nature for the thus produced standards, the issue at stake is that of how standards, rather than being true or right, coincide with one another, fit a standardised value "within an acceptable uncertainty tolerance" (154). O'Connell locates this emergence of developing intrinsic standards in this line of argument: rather than producing true material standards that wear out, the NIST turned to intrinsic standards so to produce, "realise" standards that do not drift, do not wear out – or at the least are the least likely to. But, as he comments, "simplicity is never simple": as realisation experiments took place, it became realised that reproducing experiments was no straightforward endeavour due to the "tremendous surrounding complexity required to achieve this particular kind of simplicity" found in accurate standards. Inadequacies in experiments were spotted out and it became realised that having operators travel may become, and even remain necessary, at the least periodically, and that any reporting practices on how to best perform the required experiments may remain lacking crucial information if for good use and results (155-157).

The second step in O'Connell's analysis in this second example is concerned with the issue of authority, that is, the issue of which standards to choose: the more accurate one or the more practical one? (157-159). He then expands on the authority-bearing role of the NIST in the process of electing some specific cesium tubes as ground for a good time interval standard, pointing out at how the debates reveal how, in practice, "agreement with Nature does not seem as important as interlaboratory agreement," with standards being examined as regards to their agreement with Nature only in circumstances wherein consistency and stability of measurements is at stake.

O'Connell's last step in his account of standards at the NIST consists of comments on how metrological activity, though crucially supporting activities in the lab, is often invisible to the non-metrologist's eye, as "part of the culture of science that effaces the work needed to make its universality self-evident" (159). On this respect, O'Connell comments on the role of the US Department of Defence as enforcer, through the NIST, of regulation regarding standards, measurements and calibration. This has led to a series of formal specifications and definitions of traceability that permits to trace out and map the connections between standards in use and a handful of standards held at NIST, and to evaluate easily the discrepancies between them. Traceability in O'Connell's account is these 'Golden Calf' procedures that permit connecting tangible objects in use with what they purport representing; these procedures were first embodied by NIST standards' auditors travelling around, and gradually have taken the new form of paper documents and written reports of test experiments, documents that now "stand for things" and "replace circulating auditors." In the same time, work on new intrinsic and artefact standards permits the development of devices built with auditing capability and a rising automation, which, in turn, increases universality of standards (160-162).

O'Connell's conclusion mirrors his introduction. He wraps up the comments developed on universality and standards developed in the paper using practical examples, esp. examples drawn from the US Military's invisible dependence upon good standard maintenance for its operations. As he writes, the technoscience of standards is based upon an "invisible network over which its products and measurements circulate to demonstrate its universality," and the main issue to look at here, is that of "*how* it does that – by establishing the authority of a particular representative, circulating it, and assuring that comparisons are made to it [...] The apparent universality of science is tribute to the power of a collective rendered stable by the pre-circulation of stable objects [...] Scientific entities are not universal until scientists or their technicians take the trouble to make them so." (165-166).

Démarche/Approach
Assembly of SSK-like case studies on practices leading out to philosophical comments.

Apports Spécifiques/Specific Inputs

1/ Additional keywords
'universality', 'technoscience', Fleck, 'Denkkollektiv', standardisation, normes, erreurs, circulation et diffusion des savoirs, précision et pratiques scientifiques, SSK, Schaffer, quantification, US National Bureau of Standards/National Institute of Standards and Technology

2/ As regards to the theme
The paper is an interesting introduction to the theme of metrology in its relationship to standards and norms, going beyond the usual claim that when something is measured it is known. Interesting comments on the paper can be found in Golinski, J., Ed., 1998, *Making Natural Knowledge: Constructivism and the History of Science* (Cambridge: Cambridge University Press), on pp. 175-178.

3/ Interesting references
The paper is ripe with interesting references, including some classic ones (Fleck, Latour), some related to measurement standards, i.e. in standardisation organisation, and some more specifically related to measurement studies, i.e. the early work of S. Schaffer on measurement units and practices, mostly otherwise scattered in edited volumes.

Among the references the most interesting, esp. as regards to contemporary (†) and posterior (‡) development in the literature as regards to the issue of measurement and universality, and social and material collectives, and to writings by Joseph O'Connell and by the NBS/NIST:

> † Bud, R. & S.E. Cozzens, Ed., 1992, *Invisible Connections: Instruments, Institutions and Science* (Bellingham, WA: SPIE Optical Engineering Press) ∞ Collins, H.M. *Changing Order* ∞ Fleck, L.,

1979, 1st ed. 1935, *Genesis and Development of a Scientific Fact* (Chicago: The University of Chicago Press, first published in 1935 under the title *Entstehung und Entwicklung einer Wissenschaftlichen Tatsache: Einführung in die Lehre vom Denkstil und Denkkollektiv*) ∞ Gooday, G.J.N., 1990, "Precision measurement and the genesis of physics teaching laboratories in Victorian Britain," *British Journal for the History of Science,* 23, 25-51 ∞ Hallock, W. & H. Wade, 1906, *Outlines of the Evolution of Weights and Measures* (New York: MacMillan) ∞ Latour, B., 1987, *Science in Action* (Cambridge, MA: Harvard University Press) ∞ Lynch, M., 1988, "Sacrifice and the Transformation of the Animal Body into Scientific Object: Laboratory Culture and Ritual Practices in the Neurosciences", *Social Studies of Science*, 18(2), 265-289 ∞ Lynch, M., 1991, "Method: Measurement – Ordinary and Scientific Measurement as Ethnomethodological Phenomena", in Button, G. (Ed.)(1991), *Ethnomethodology and the Human Sciences*, Cambridge: Cambridge University Press, 77-108 ∞ O'Connell, J., 1992, « The Fine-Tuning of a Golden Ear: High-End Audio and the Evolutionary Model of Technology », *Technology and Culture*, 33 (Jan. 1992), 1-37 ∞ Rouse, J. (1987), *Knowledge and Power* (Ithaca, NY: Cornell University Press) ∞ Schaffer, S., 1992, "Late Victorian Metrology and its Instrumentation: A Manufacture of Ohms", in Bud, R. & S.E. Cozzens (Ed.)(1992), *Invisible Connections: Instruments, Institutions and Science* (Bellingham, WA: SPIE Optical Engineering Press), 23-56 ∞ Simmons, J.D., Ed., 1991, *NIST Calibration Services Users Guide 1991* (Gaithersburg, MD: National Institute of Standards and Technology, NIST Special Publication 250) ∞ Smith, C. & M.N. Wise, 1989, *Energy and Empire* (Cambridge: Cambridge University Press).

‡ Gooday, G.J.N., 1995, "The Morals of Energy Metering: Constructing and Deconstructing the Precision of the Victorian Electrical Engineer's Ammeter and Voltmeter," in Wise, M.N. (Ed.)(1995), The Values of Precision, 239-281 ∞ Gooday, G.J.N., 2004, *The Morals of Measurement. Accuracy, Irony, and Trust in Late Victorian Electrical Practice* (Cambridge: Cambridge University Press) ∞ Power, M., Ed., 1996, *Accounting and Science: Natural Inquiry and Commercial Reason* (Cambridge: Cambridge University Press, 'Cambridge Studies in Management' 26)[3] ∞ Schaffer, S., 1995, "Accurate measurement is an English science," in Wise, M.N. (ed.)(1995), 135-170 ∞ Schaffer, S., 1997, "Metrology, Metrication, and Victorian Values," in Lightman, B. (ed.)(1997), *Victorian Science in Context* (Chicago: University of Chicago Press), 438-474.

4/ Some interesting critical comments

O'Connell develops some interesting criticisms as regards to the limits of the usefulness and validity of Latour's work, which has now become a classic when it is to treat issues related to the circulation of people and artefacts and the making and validation of knowledge and related outputs. See e. a.: "*While Latour provides some of the analytic vocabulary used in this paper, and was one of the first to identify the importance of metrological practices to the universality of technoscience, his work to date appears more concerned with noting that heterogeneous metrological collectives exist and celebrating what they allow technoscientists to do, rather than exploring how different types of connections make up such collectives, what resists their formation, and how they were formed against this resistance. Rouse provides some of the theoretical resources for a more sophisticated understanding of collectives, centres of calculation, and the creation of universality, but without empirical support*" (italics added, note 3, on p. 167). More closely related to the issue of standards, O'Connell has got some

[3] With e. a. contributions by Bruno Latour (« Foreword: The flat-earthers of social theory »), Michael Power (« Introduction: From the science of accounts to the financial accountability of science »), Theodore M. Porter (« Making things quantitative »), Myles W. Jackson (« Natural and artificial budgets: Accounting for Goethe's economy of nature »), Timothy L. Alborn (« A calculating profession: Victorian actuaries among the statisticians »), Peter Miller and Ted O'Leary (« The factory as laboratory »), Keith Robson (« Connecting science to the economic: Accounting calculation and the visibility of research and development »), Brad Sherman (« Governing science: Patents and public sector research »), John Law and Madeleine Akrich (« On customers and costs: A story from public sector science »), Philip Mirowksi (« A visible hand in the marketplace of ideas: Precision measurement as arbitrage »), and Steve Fuller (« Toward a philosophy of science accounting: A critical rendering of instrumental rationality »).

comments throughout, e. a. in note 5 wherein he comments on the use of terms as realization and representation in technical milieus in a critical constructivist way (this is not done for instance in Mallard's paper summarised elsewhere).

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