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Advances in maritime education and training: The case of new competences of electro-technical officers complying with international regulations

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ABSTRACT

A notable trend of maritime education and training development has been observed in recent years. One of the signs of this process was the introduction of new standards of competence for Electro-Technical Officers into the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, being one of the most important global and legal instruments within maritime education and training. This paper briefly presents a structure of the STCW Convention, taking into account the new competences, as well as the reasons and tools for their development and implementation. A key point of the article is statistical analysis of the impact of new legislation on the professional career development of Electro-Technical Officers based on the case study of Poland. Some concluding remarks concerning the employability, professional stabilization and new perspectives of ETOs are formulated.

1. Introduction

The highest values for the world community today, whether maritime or other, are "safety", "quality" and "environmental friendliness" (Yamamoto, 2002). In the context of today's shipping or wider maritime economy, these values have a fundamental importance, because of the global character of this kind of cooperation and activity. One of the key tools for achieving the assumed goals is continuous development of maritime education and training (MET). This development has been initiated and created for, legal and technological reasons. In consequence, the progress of MET is stimulated and driven by the innovative research and implementation of new legislative instruments and new technologies, which require higher qualifications of seafarers. Maritime education and training (MET) is one of the aspects of Vocational Education and Training (VET), which is characterized by, among others, Boahin & Hofman (2012). In that publication some experiences concerning the more significant forms of VET, competency-based training, are presented in the wake of important observations. Firstly, vocational education and training is driven by multiple factors, such as the global economy, industry, restructuring and governmental policy initiatives. Secondly, the world of work keeps on changing due to the progress in science and technology (Boahin & Hofman, 2012). This leads to changes in tastes and preferences, which necessitate adaptations in VET teaching and learning. MET is also developed due to the changes within the international standards, such as the STCW-95 (2010) Convention (STCW-95, 2010) signed by the majority of world governments under the auspices of the International Maritime Organization (IMO). In this context, the main goal of education is to prepare an individual for life which involves multiple roles in order to function effectively in the community, e.g. seagoing service on board ships. The last question is very closely related to the employability problem, in other words to labour market changes, including seafarer supply and demand. The university case study presented and discussed in Smith, Clegg, Lawrence, & Todd (2007) has an employability framework which includes six elements to be embedded in the courses to promote employability:

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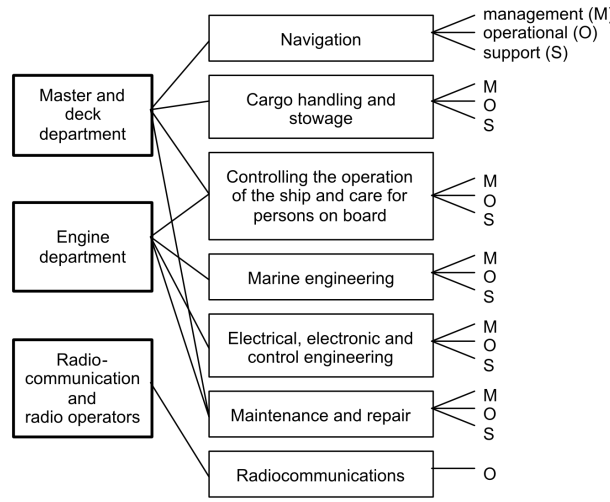
1. the progressive development of autonomy
2. the development of skills
3. personal development planning
4. the inclusion of activities similar to those required in the external environment
5. student reflection on skills and knowledge and how these can be transferred to different contexts
6. the encouragement of career management

It is very easy to observe that the conditions and requirements formulated as being general in points 2, 4 and 5 have been strictly adapted to the commonly accepted MET standards. Maritime Education and Training (MET) evolves along with the fast growth of the maritime industry. It faces many new requirements (Wei, 2002) in the progress of such development such as the requirement for further enhancement of seafarers' practical skills and ability under the new STCW-95 (2010) convention, the requirement to introduce new training methods (dedicated devices, simulators, labs), and other requirements and demands from the maritime industry side. The usual way of implementing an initiative such as STCW-95/2010 requirements covers theoretical education, practical skill training as well as assessment and examination (Wei, 2002). Practical skill training can be done via simulators, CBT (computer based training) and on board training. The process of meeting those requirements can be seen as a new development of MET. Additionally, for the countries interested in crew-manning supply, the quality of their MET is one of the main factors affecting the competitiveness of their seafarers in the crew-manning market (Wei, 2002). Some interesting analyses concerning the international competitiveness of shipping companies, including among others the current situation in the maritime sector and its dependence in foreign labour aspects, are presented in Inoue (2011).

2. Standards of competence of seafarers in the light of the International Maritime Organisation regulations

Standards of competence in seafarers should be considered from a global, world-wide point of view. Under this assumption, discussed standards are a key point of the maritime education and training (MET) system which organization is described, among others, in MET (1997). A wide perspective of the MET discussed in MET (1997) covers such elements as the concepts of learning, learning resources and educational technology, the organization of MET, fundamentals of assessment and evaluation, and finally presents an approach towards specialisation. One of the most important aspects of MET is the notion of competence. It is commonly considered that to achieve competence a learner has to acquire relevant knowledge and develop abilities; to be awarded the appropriate certificate, this needs to be assessed. More detailed explanations (Baillie, 1997) describe this notion thus: "Competence is the possession of the skills and knowledge required for the award of Certificate of Competency", with additional information that "at sea, competence is more likely to be defined as a capacity to do a job efficiently in any circumstances likely to arise". But there also exists the second dimension of competence, which involves

Figure 1: Relationships among departments on ships and functions according to the meaning of the STCW Convention and Code, (STCW-95, 2010).



Source: Authors

personal attributes and professional values (Baillie, 1997). To better understand, what a concept of standards of competence in the context of MET means, some information based on the IMO instruments being the fundamental documents in this field i.e. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention and STCW Code) 1978 as amended in 1995 and 2010 (STCW, 1978 ; IMO, 2011) respectively, have been briefly presented below. Firstly, it was stated that the standard of competence means the level of proficiency to be achieved for the proper performance of functions on board ship in accordance with the internationally agreed criteria as set out, and incorporating prescribed standards or levels of knowledge, understanding and demonstrated skills (IMO, 2011). Secondly, these standards and related abilities are adequately defined and grouped as appropriate under the seven functions (Fig. 1) and the three different levels (management, operational, support) of responsibility, in accordance with the STCW Convention and STCW Code (IMO, 2011). Functions and levels are defined separately according to the fields of activity of seafarers on board, described in the related chapters dedicated to the master and deck department, engine department as well as radio communication and radio operators (IMO, 2011), respectively. The relationships among departments on ship, functions and levels are illustrated in Fig. 1.

It should be added that this simplified description concerns only the departments on ship and does not contain information regarding the special training requirements for personnel on certain types of ships; nor does it provide further information about emergency, occupational safety, security, medical care and survival functions as well as alternative certification or watchkeeping problems. The Author is of the opinion that such issues are beyond the main scope of this paper. On the other hand, it is necessary to mention that in each ship department there are appropriately defined groups and positions of crew members, with related functions and levels of responsibility. For example, a group of Electro-Technical Officers (ETOs), belongs to the engine department (IMO, 2011) which also accommodates the following positions: chief engineer officers and second engineer officers, officers in charge of an engineering watch in a manned engine-room or designated duty engineers in a periodically unmanned engine room, ratings forming part of an engineering watch, ratings as able seafarer engine in a manned engine-room or designated to perform duties in a periodically unmanned engine-room, and Electro-Technical Ratings. For consideration of ETOs it is also important that at the moment, this officer position is defined only at the operational level. Moreover, each function is connected with a given, defined in (IMO, 2011), number of competences. For example the standards regarding Electro-Technical Officers (ETO) are established by Regulation III/6 of the Annex STCW Convention and Sections A-III/6 and B-III/6 of the STCW Code (IMO, 2011). Examples of the selected competences for the structural descriptions of the function electrical, electronic and control engineering at the operational level for a given competence, based on IMO (2011), is illustrated in Table 1.

Summing up, a specification of minimum standards of competence covers the list of the tasks, duties and responsibilities (column 1), the list describing the minimum knowledge, understanding, and proficiency required for certification (column 2) and the list of evidence, of having achieved the required standard of competence (column 3 and column 4). Looking at Table 1, it is noted that there are some similarities between the MET and EFQ (European Framework of Qualifications) systems, developed as a result of the Bologna Process (EFQ, 2008); for example in the STCW Convention there are descriptors of qualifications (KUP): knowledge, understanding, proficiency and under the EFQ standards, the descriptors of education effects are expressed by: knowledge, skills and social competences. On the other hand, three tiers of qualification in the EFQ system–Bachelor, Master and Doctor–have no direct connection with appropriate levels of the qualifications management, operational and support used in the MET system.

3. Why the MET standards for ETO had to be developed and implemented

A fundamental reason for this process is a rapid and continuously running development in electrical and electronic engineering on ships. This progress covers two layers: technical, related to the complexity of the marine electrical and electronic devices construction and control, and a personal competence-related aspect. This is connected to new requirements for watchkeeping officers responsible for control, maintenance, diagnostics and repair of electrical and electronic installations on board ships. The first is based mainly on the development of the new technology-based, sophisticated ships like passenger ships, large ferries, chemical and gas tankers, container vessels, oil rigs suppliers and large offshore structures. At the same time, a total power of electrical energy receivers installed in new ships in many cases reaches the values up to 80-100 MW, and the level of applied voltages can even reach 11kV. A significant component of these technologies is based on the assumption that the computer control systems are generally used in the engine room, on the bridge and in cargo loading and discharging systems, and they are supervised by the distributed measurement and control ship systems. Under the described conditions many new problems have been observed and new challenges on how to overcome them, appeared. This was a starting point to the second aspect that concerns the new competences and KUP (knowledge, understanding and proficiency) for highly qualified staff, and dedicated mainly to the electrical, electronic and control engineering issues. Safe operation of many technologically sophisticated ships today is greatly dependent on satisfactory skills and qualifications in the electrical, electronic and control engineering field being at all times available and more often developed on board. That is why such big power plants and electric motors used for propulsion of the vessel as previously mentioned, also very complicated computer control and monitoring systems on board ships, should be maintained and repaired by a highly competent and well-prepared ETO duties person. Such a person, responsible for repair and maintenance of electrical and electronic installations on board ships, must have thorough knowledge, which is not possible to achieve only by working for a long period in the engine department of the ship. A deep theoretical background and appropriately conducted training based on specialised laboratories, simulators and on board ships is needed. It is worth adding that the majority of shipowners presently have employed electrical/electronic officers but at the same time, many contrary situations were noted; for example a lack of sufficient qualifications amongst marine engineers, and simultaneously, incidents of not hiring electrical engineers on board the ship were reported. In consequence, several opportunities to determine the problems with failures of an electrical and electronic origin were missed, through lack of detailed problem analysis. One of the strange and well-documented cases concerning the failure of generating set's circuit breaker during a voyage of passenger ship MS Statendam was analysed and described in MER (2006). The most intriguing were the statements formulated by the Transport Safety Board of Canada. Firstly, it was concluded that none of the senior engineers on board had theoretical or practical education in 6.6 kV generation, distribution and trouble shooting and secondly, it was said that the Seafarers Training, Certification and Watchkeeping (STCW) code however, did not identify electricians as a seafaring profession and did not specify a minimum internationally applicable standard for their education, training and competence (MER, 2006). It is obvious that this kind of thinking, based on the version of the STCW Convention and Code (STCW, 1978) existing at that time, had to be changed. More detailed information concerning the ETO background, progress in related standards and long, many-year legislative processes may be found in Wyszkowski, Mindykowski & Wawruch, (2009) and Wyszkowski & Mindykowski (2013). It is worth noting that previously presented and commented in MER (2006) statements well correspond to the way of examining the role of human factors in maritime accidents at three different levels proposed and discussed by Chauvin (2011) as

Table 1: Function: Electrical, electronic and control engineering at the operational level.

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Monitor the operation of electrical, electronic and control systems	Basic understanding of the operation of mechanical engineering systems, including: 1 prime movers, including main propulsion plant 2 engine-room auxiliary machinery 3 steering systems 4 cargo handling systems 5 deck machinery 6 hotel systems	Examination and assessment of evidence obtained from one or more of the following: 1 approved in-service experience 2 approved training ship experience 3 approved simulator training, where appropriate 4 approved laboratory equipment training	Operation of equipment and systems is in accordance with operating manuals Performance levels are in accordance with technical specifications

Source: Author

the level of individual factors of first-line operators, the level of social factors and the level of systematic or organizational factors.

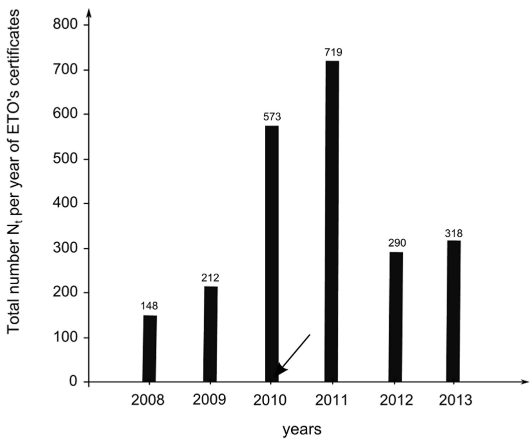
4. A short description of the minimum standards of competence for Electro-Technical Officers

The certification system is one of the key processes in the integral production system of shipping services of a country. It is the quality control mechanism within the system to check the quality and competence of seafarers as the vital element of the shipping services (Yamamoto, 2002). The mandatory minimum requirements for certification of Electro-Technical Officers were formally included in the Section A-III/6 and for certification of Electro-Technical Ratings, in the 2011 edition of STCW Convention and STCW Code (IMO, 2011). These are the first standards in IMO's history for electro-technical personnel and now the international community of seafarers is equipped with the appropriate legal instruments in this matter. The standards regarding ETO are one-level standards and correspond to the operational level. The minimum standards of competence for ETO, specified in IMO (2011), cover 18 competences divided into three functions: 1. Electrical, Electronic and Control Engineering; 2. Maintenance and Repair, as well as 3. Controlling the Operation of the Ship and Care for Persons on Board. All functions are dedicated to the operational level. The competences of the first function concern monitoring the operation of the electrical electronic and control systems, including propulsion and auxiliary machinery, the operation of generators and distribution systems as well as the operation and maintenance of high voltage (above 1kV) power systems, and finally the usage of internal communication systems and English at an adequate level. The competencies of the second function cover the maintenance and repair of KUPs related to electrical and electronic equipment, automation and control systems of main propulsion and auxiliary machinery, bridge navigation equipment and ship communication systems, and also electrical, electronic and control systems of deck machinery and cargo-handling equipment, and finally, related to control and safety systems of hotel equipment. The competences of the third function are similar to the competencies for other engine and deck officers at the operational level and adequate KUPs describe the issues of pollution prevention requirements, prevention, control and fire-fighting on board, operation of life-saving appliances, medical first aid on board ships and finally, application of leadership and teamworking skills. All the above presented standards of competence were the basis for the development of the new tools supporting ETO's standards implementation. Firstly, a new "IMO Model Course on Electro-Technical Officer" (IMO, 2013a), was accepted, and secondly, the "On Board Training Record Book" (IMO, 2013b) was elaborated and disseminated (Wyszkowski & Mindykowski, 2013). The content of the Model Course for ETO (IMO, 2013a) has been carefully designed in order to assure full coverage of the necessary requirements, and the record book (IMO, 2013b) should be used as a basis for the recognition of the officer's knowledge and experience, leading to the award of the certificate (Wyszkowski & Mindykowski, 2013).

5. Impact of new standards on ETO's certification: the case study of Poland

The inclusion of Electro-Technical Officers into a flagship IMO Convention, i.e. STCW Convention and STCW Code, took place at the end of June 2010 during the Diplomatic Conference in Manila. This held a crucial importance in the IMO standards development in general, because it opened up an opportunity to establish and develop a track of the ETO's professional career. This full track could be dedicated to Electro-Technical Ratings, Electro-Technical Officers and senior Electro-Technical Officers (Wyszkowski & Mindykowski, 2013), as it includes those responsible for maintenance and repair of electrical and electronic systems, equipments and installations on board ships. The first announcement of the emerging trends concerning this idea is very clearly visible and documented on the basis of the case study of Poland. The example based

Figure 2: Total number per year Nt of Electro-Technical Officer (ETO) certificates issued in Poland 2008?2013; the year of the approval of new STCW ETO's legislative solution has been marked by an arrow.



Source: Author

on the Polish experience seems to be an concept made possible because Poland was one of the leading countries in the worldwide understanding of the legislative progress towards the new IMO rules in the area under discussion (Wyszkowski & Mindykowski, 2013), (Mindykowski, Charchalis, Przybylowski, & Weintrit, 2013). Poland has a very good tradition and has an internationally recognized reputation in maritime education and training (Mindykowski, Charchalis, Przybylowski & Weintrit, 2013a), (Mindykowski, Charchalis, Przybylowski & Weintrit, 2013b), (Mindykowski, 2013). Presented case study shows a significant impact of the newly introduced changes in IMO STCW Convention and Code on the certification process of Electro-Technical Officers in Poland in the years 2008-2013. The analysis carried out is based on the assumption that the year 2010 was a critical date; it means a breaking point for the analysed process. The related data are illustrated in Table 2 and Fig. 2, in the part concerning the total number per year Nt of ETO certificates.

Taking into account the data shown in Table 2 and assuming that a reason for the acceleration process of the certification appears in the moment corresponding to t0 = 2010, a smoothing approximation of the data available for t = t0 (2008, 2009, 2010) and later on an extrapolation of these data for the range t = t0 (2010, 2011, 2012, 2013) was carried out. In the first step, the approximation by means of the method of least squares was undertaken. Assuming approximation with use of polynomial of the second order, we were looking for an approximating function expressed by the formula (Ralston, 1965):

$$N_t = F(t) = C_0 g_0(t) + C_1 g_1(t) + C_2 g_2(t) \qquad (1)$$

where: $g_0(t) = 1$, $g_1(t) = t$, $g_2(t) = t^2$, C_0, C_1, C_2 - calculated coefficients

By solving the system of equations:

$$\left.\begin{aligned}
\sum_{i=0}^{n}[(C_0 \cdot g_0(t_i) + C_1 \cdot g_1(t_i) + C_2 \cdot g_2(t_i) - N_{ti}) \cdot g_0(t_i)] = 0\\
\sum_{i=0}^{n}[(C_0 \cdot g_0(t_i) + C_1 \cdot g_1(t_i) + C_2 \cdot g_2(t_i) - N_{ti}) \cdot g_1(t_i)] = 0\\
\sum_{i=0}^{n}[(C_0 \cdot g_0(t_i) + C_1 \cdot g_1(t_i) + C_2 \cdot g_2(t_i) - N_{ti}) \cdot g_2(t_i)] = 0
\end{aligned}\right\} \qquad (2)$$

where: $t_i = 2008, 2009, 2010$, respectively, N_{ti} - total number per year of ETO certificates issued in 2008, 2009, and 2010, respectively

The coefficients C_0, C_1 and C_2 were obtained:

$$C = \begin{pmatrix} C_0 \\ C_1 \\ C_2 \end{pmatrix} = \begin{pmatrix} 1.0328 \times 10^4 \\ -2.4605 \times 10^3 \\ 148.5 \end{pmatrix}$$

Having an approximating function $F(t)$ described by means of dependence (1) we determine its extrapolation for the data covering the range $t \in \{2010, 2011, 2012, 2013\}$. The $F(t)$ function (Fig. 3) describes the increasing tendency of total number N_t of analysed certificates within the period from 2008 to 2013, taking into account a significant legislative change in 2010, being in fact a breaking point of the analysed trend. In Fig. 2 this process is illustrated by curve 1. In the second step, a smoothing approximation of the data for $t`t_0$ (it means for years 2010, 2011, 2012 and 2013) has been done and the result was compared with the previous extrapolation. Using the same mathematical tool as in the case of the $F(t)$ function, the following is obtained (Ralston, 1965):

$$F'(t) = C'_0 \cdot g_0(t) + C'_1 \cdot g_1(t) + C'_2 \cdot g_2(t) \qquad (3)$$

where

$$C' = \begin{pmatrix} C'_0 \\ C'_1 \\ C'_2 \end{pmatrix} = \begin{pmatrix} -2.0164 \times 10^4 \\ 559.1 \times 10^3 \\ -29.5 \end{pmatrix}$$

This function can be interpreted as a related continuation of the tendency changes in total number of analysed certificates, within the period from 2010 to 2013. In Fig. 2 this stage of the analysis is shown by curve 2. Summing up, a difference, after integration:

$$I_{ETO} = \int_{t_1}^{t_2} \Delta(t)\, dt \qquad (4)$$

where: $\Delta(t) = F(t) - F'(t)$, t_1 year 2010, t_2 year 2013

We can treat as a measure of impact of new standards of competence in the ETO certification process in Poland. For the given data, this measure reaches the value $I_{ETO} = \int_{t_1}^{t_2} \Delta(t)\, dt = 3.879 \times 10^3$, and illustrates a discussed impact on a considered certification process.

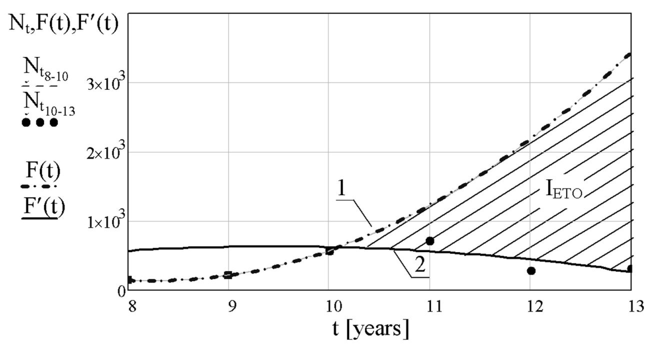
The next sequences of the analysis addressed the detailed questions regarding the number of refreshed certificates and newly issued certificates. The analysis carried out showed that a

Table 2: Data concerning the certification process of Electro-Technical Officers in Poland 2008-2013.

Number of ETO certificates	Years					
	2008	2009	2010	2011	2012	2013
Total (N_t)	148	212	573	719	290	318
Refreshed (N_r)	93	149	514	635	190	198
Newly issued (N_n)	55	63	59	84	100	120

Source: Authors

Figure 3: Procedure of determining of the impact of newly introduced changes in IMO STCW Convention and STCW Code on the certification process of ETOs in Poland.



Source: Author

dominant influence on the process under discussion had a number of refreshed certificates. An explanation of this situation is, that in the last few years many ship electricians halted their career in that profession and were looking for new possibilities, for example moving to become marine officers, because of the lack of opportunities to develop under the previous legislative system. The Author of this paper is aware that these figures give a simplified description of the discussed effect because the amount of analysed data is limited; but on the other hand, there are specific one-year-cycle data, aggregated and elaborated for all Polish Administration Offices for the period of some years, which anticipated the described time of change (2010) and followed it. In consequence, this analysis well illustrates a considered process and assesses its cumulative effect.

6. Conclusions

Due to the continuous technological development as well as the newly required qualifications and skills for maintenance and repair of electrical/electronic systems, equipment and installations, there is a significant increase in the employment of properly qualified Electro-Technical Officers. Such specialists are the crew members of cruise vessels, large ferries and all kinds of special purpose vessels, and therefore their qualifications and competences had been standardised at the international level in the STCW Convention. As in the case of other officers, there is a need to implement and develop the newly established IMO Model Course for Electro-Technical Officers and Onboard Training Record Book. These documents should be helpful to establish procedures for ETOs' education and training. Taking into account a previous IMO Maritime Safety Committee announcement and recommendation (Wyszkowski & Mindykowski, 2013), the next essential step should be oriented towards the adoption of appropriate MET standards for Senior Electro-Technical Officers. It is very important to open a full track of their professional career, for Electro-Technical Ratings, Electro-Technical Officers and senior Electro-Technical Officers for persons responsible for maintenance and repair of electrical and electronic systems, equipment and installations on board ships. A presented case study based on the Polish experience concerning the impact of new legislation on Electro-Technical Officers careers confirms an activation of the "latent possibilities" of this group and shows its professional re-orientation, opening a new chapter in the Electro-Technical Officer career development.

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