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(Research Article)

Technological regulations as an instrument for ensuring safety at oil refining facilities

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Abstract

The paper analyses the functional role of technological regulations as a basic instrument for managing industrial safety at oil refining facilities. Within the framework of the study, the limitations of the traditional system for managing technical documentation are critically examined, and the potential of modern digital solutions digital twins, automated process control systems (APCS) and artificial intelligence tools for overcoming these limitations is analysed. Particular attention is paid to practical issues of integrating Management of Change (MoC) processes and audit procedures with digital systems for monitoring production conditions and for tracking compliance with regulatory requirements. The central thesis of the paper consists in substantiating that the effectiveness of regulations is directly determined by the speed and quality of their adaptation to changing real operating conditions. To achieve this objective, methods of systems analysis, comparative analysis and synthesis of accumulated practical experience are applied. In the concluding part, the proposed conceptual model of a live regulation is formalised and its advantages are demonstrated from the standpoint of reducing operational risks. The results presented are addressed to process engineers, industrial safety specialists and managerial personnel of oil refining enterprises.

Keywords: Technological Regulation; Industrial Safety; Oil Refining; Process Safety Management (PSM); Digitalization; Management of Change (Moc)

1. Introduction

The oil refining industry belongs to the group of the most high-risk and capital-intensive sectors of real production, where any deviation from design parameters can lead to large-scale man-made incidents. In this regard, ensuring technological safety at oil and gas treatment, transportation and refining facilities acts not merely as an important task, but as an unconditional and strategic priority [1]. At the same time, even under conditions of the formal functioning of comprehensive Process Safety Management (PSM) systems, accidents do not disappear. The analysis of major incidents systematically summarized by the U.S. Chemical Safety Board [4] shows that the root causes of disasters are often rooted not in the absence of a regulatory framework as such, but in its inconsistency with the actual operating conditions, in the accumulation and neglect of gradual operational deviations, and in the insufficient maturity of Management of Change (MoC) processes [6].

In parallel, the Fourth Industrial Revolution is radically restructuring the technological landscape of the industry, implying the wide implementation of digital twins [8], modern automated process control systems (APCS) [9] and artificial intelligence-based solutions [3]. These tools form a fundamentally new environment for the functioning of production systems, in which traditional approaches to safety begin to experience methodological and practical limitations. Under these conditions, the classical paper-based or static process regulation, revised at multi-year intervals, becomes a bottleneck of the management system and a potential source of additional risk, since it does not keep pace with the dynamics of operation and the accumulating modifications.

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The aim of the study is to substantiate the proposition that process regulations can serve as a truly effective instrument for ensuring safety at oil refining facilities only under the condition of their dynamic adaptation, maintenance of constant relevance and deep integration into a unified digital ecosystem of production management.

To achieve this aim, it is proposed to analyse the role and identify the key limitations of traditional (static) process regulations in the structure of Process Safety Management (PSM); to investigate the impact of digitalization processes (IoT, APCS, AI) [1, 2, 3] on the life cycle and operational application of process regulations; and to propose a conceptual model of a live regulation based on the synthesis of advanced practices [7] and the author's practical experience in updating operational documentation and digitalizing processes at SiburTyumenGas JSC.

The scientific novelty of the work lies in the development and theoretical substantiation of the concept of a live regulation, which transforms the process regulation from the status of a passive administrative and regulatory barrier into the status of an active, dynamically changing element of the process control system, capable of promptly responding to changes in external and internal conditions.

The author's hypothesis is formulated as follows. In modern conditions, the effectiveness of process regulations is determined not so much by the initial rigour and detail of their development as by the speed, accuracy and reproducibility of their adaptation to changes, both formalized (implemented through MoC procedures) and informal, identified on the basis of data from APCS and other digital subsystems. A static regulation in such an environment becomes a generator of additional risk, whereas a live (digital, integrated and continuously updated) regulation turns into an instrument for deliberate and controlled handling of this risk.

2. Materials and methods

In preparing the article, a set of general scientific methodological approaches was used. The methodological core of the study was systems analysis, which made it possible to consider the technological regulation not as an autonomous textual artefact, but as a functional element of a complex sociotechnical system that includes personnel, technological equipment, automated control loops (APCS), as well as corporate industrial safety and risk management frameworks within the PSM model.

Comparative analysis was applied to juxtapose the traditional paper-based approach to managing regulatory documentation with modern practices based on the principles of digitalization of production processes. This made it possible to identify both the key advantages of digital solutions (in terms of updating, accessibility and integrability of regulations) and the institutional, organizational and technological barriers to their implementation. The method of synthesis was used to integrate theoretical propositions drawn from foreign scientific literature with empirical material based on the author's practical experience accumulated in the positions of senior technologist at SiburTyumenGas JSC and and chief specialist at Irkutsk Oil Company.

The information base of the study was formed by foreign scientific publications selected from the databases Google Scholar, ResearchGate, MDPI and specialized industry repositories (including materials of the U.S. Chemical Safety Board).

The search for relevant sources was carried out in English using the following keywords and phrases: technological regulations, operating procedures, process safety management (PSM), oil refining safety, digitalization in process industry, management of change (MoC), human factors procedural compliance, anomaly detection industrial networks.

The main criteria for the selection of publications were their substantive relevance to the stated problematics, their focus on the oil and gas and oil refining sector, and their emphasis on the influence of digital technologies on operational procedures and the production safety assurance system. The corpus of analysed materials included both academic studies and authoritative technical reports, which ensured a multifaceted and interdisciplinary perspective on the problem.

A special emphasis in the methodological framework was placed on the integration of the author's practical experience. Empirical data on the management and supervision of digitalization projects, the development and updating of technical and operational documentation (regulations, instructions), as well as on interaction with supervisory authorities at a specific production site were used as a basis for the verification, clarification and adaptation of the theoretical constructs and models identified in the analysed sources to the realities of the functioning of a modern petrochemical enterprise.

3. Results

The analysis of scientific publications and accumulated industrial experience made it possible to structure current views on the role of the process safety manual in the industrial safety assurance system and to identify key groups of problems that are addressed by contemporary management approaches.

The process safety manual (TP) acts as a structural element of the process safety management (PSM) system. It normatively establishes safe operating limits, start-up and shutdown algorithms, procedures for maintaining normal operating conditions, as well as prescriptions for actions in abnormal and emergency situations. In fact, such elements of PSM as Management of Change (MoC) [6], Process Hazard Analysis (PHA) and Pre-Startup Safety Review (PSSR) [6] represent institutionalized mechanisms for the development, refinement and updating of the process safety manual.

However, the classical model of working with manuals has a fundamental limitation, namely their static nature. After development and approval, the process safety manual, as a rule, exists in the form of a paper document or a PDF file. The resulting gap between work-as-imagined and work-as-done forms a latent layer of risk. CSB investigations [4] have repeatedly recorded that incidents unfold in situations where personnel rely on customary practice rather than on a formalized procedure, or where the procedure itself is outdated and no longer reflects the totality of accumulated minor changes in the process.

3.1. Influence of the human factor and audits on the implementation of manuals

The practical feasibility of the requirements of the process safety manual is directly mediated by the human factor. The effectiveness of the manual is determined by the degree of its embeddedness in the operator's routine and its conformity to real working conditions. Audit tools [5] are intended to ensure control over compliance with the requirements of the manual. In practice, however, audits [5] are often reduced to checking formal indicators: the presence of a signature indicating familiarization, the correctness of log entries, and the consistency of records with the text of the manual. Under such conditions, the audit is poorly suited to identifying that the manual itself has been transformed into an ineffective or even unsafe document under the influence of the gradual drift of process parameters. As a result, an enterprise may demonstrate successful performance in audit inspections while simultaneously accumulating hidden risks in real production practice.

Overcoming the problem of the static nature of manuals is fundamentally related to digital transformation processes, a domain that is one of the author's key competencies (curation... of engineering projects and digitalization of processes). Modern digital solutions make it possible to transfer the process safety manual from the category of passive documentation to an active management tool [1, 7].

First, these are ASU TP systems and Advanced Process Control [9]. Safe operating limits (SOL), formalized in the manual, are integrated into ASU TP in the form of setpoints, alarm thresholds and interlocks. This level of implementation can be regarded as the initial stage of digitalization of the manual. More advanced control systems [9], as well as anomaly detection systems [2], make it possible to monitor not only parameters exceeding established limits but also atypical process behavior within formally permissible ranges, thereby ranking potential sources of hazard.

Second, these are digital twins [8]. Essentially, a digital twin is a dynamically updated and self-learning model of the process safety manual. This tool provides not only continuous monitoring of the current state of the process [8], but also forecasting of its evolution, experimental verification of planned changes in a virtual environment prior to their implementation in production (PSSR), as well as prompt adjustment of operating instructions in a mode close to real time.

Third, these are integrated management systems based on AI and data analytics (AI/Data-driven systems) [3]. The author's practical experience in reducing product loss levels and increasing industrial safety levels is directly related to the use of data analytics tools. Systems based on AI [3] have the potential to process arrays of historical information (PAZ archives, ASU TP, data from rounds and inspections) in order to identify hidden cause-and-effect relationships that precede incidents. On this basis, a foundation is created for predictive updating of manuals, that is, their proactive revision taking into account identified trends.

Taken together, the analysis shows that digitalization [1] ensures the transition from episodic, calendar-based updating of process safety manuals to their continuous verification and adaptation, turning the process safety manual into a dynamic, self-updating tool for managing industrial safety.

4. Discussion

The analysis of sources [1, 4, 9], as well as the author's industrial experience, suggests that the traditional model of process safety manual management has effectively exhausted its potential. A simple cycle of development and periodic updating of documentation is no longer sufficient; a transformation of the very paradigm of its existence and use in the production environment is required. On this basis, the author's concept of the Living Manual is formulated.

The Living Manual is understood not as a static document but as a cyber-physical system in which process safety manuals (TP) and standard operating procedures (SOP) are embedded in digital control loops and rely on a continuous stream of real-time data.

The traditional approach, which is still preserved at a significant number of enterprises, can be represented in the form of a linear or weakly closed cycle (Fig. 1).

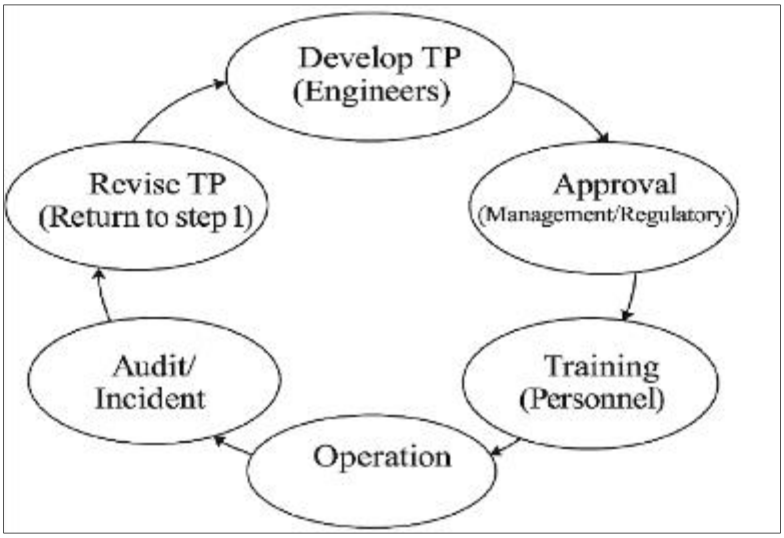

Figure 1 Traditional (static) cycle of process safety manual management [1, 4, 9]

This model is predominantly reactive in nature: updating of the process safety manual [4] in most cases is carried out post factum, either after an incident or within the framework of a scheduled audit [5]. In contrast, the Living Manual model is proposed, based on comprehensive and purposeful work and digital integration [1, 7]. The key distinction of this model is the transition from document management to management of knowledge about the process. A comparison of the two approaches is presented in Table 1.

Table 1 Comparative analysis of approaches to manual management [2, 3, 5, 6, 8]

Parameter	**Traditional (Static) Regulation**	**Living (Dynamic) Regulation**
Format	Paper document, PDF	Integrated database, digital twin
Data source	Experience of designers, incident investigations	Real-time data (APCS, IoT), AI analytics
Update frequency	Low or reactive (after an incident)	High (continuously, as required via MoC)
Operator role	Passive executor of instructions	Active participant in verification, data provider
Integration with MoC	Manual, lengthy (paper-based approval)	Digital, fast (integration with ERP/MoC systems)
Type of control	Reactive (audit of compliance with the document)	Proactive (monitoring of compliance with the process)

The implementation of this model presupposes exactly that comprehensive work, but now in the format of unifying previously fragmented functions. It concerns not only the formal digitalization of processes, but also the deep structural integration of technical services, occupational health and safety units, and design organizations into a single integrated solution. The practical implementation of this model makes it possible to address specific production tasks (Table 2) directly related to the reduction of losses and the improvement of safety.

Table 2 Application of the Living Regulation model in practice [2, 6, 8, 9]

Scenario	Response of the Static Regulation	Response of the Living Regulation
Process drift (e.g., gradual fouling of a heat exchanger that changes parameters)	Not detected. The operator gets used to the new parameters; the regulation becomes outdated. Risk.	The system detects an anomalous trend (still within tolerance, but uncharacteristic). A request for maintenance and temporary adjustment of the TR (MoC) is generated.
Implementation of a change (MoC) (e.g., replacement of a pump with an analogue having a different curve)	MoC documents are approved, but updating the TR and operator instructions takes weeks or months.	The change in the MoC automatically updates the parameters in the Digital Twin, the APCS, and the instruction on the operator's tablet.
Abnormal situation	The operator searches for the required section in the paper-based instruction. High cognitive load, risk of error.	The system recognizes the pattern of the situation and automatically displays on the operator screen only the relevant one or two TR items.

The presented concept of the Living Regulation reflects the vision of the next stage in the development of industrial safety management systems. Within its framework, the focus shifts from formal compliance with potentially obsolete prescriptions to the continuous adaptation of regulatory requirements to the actual conditions of production operation. This model, based on comprehensive and purposeful work on digital transformation [1, 7] and advanced cross-functional interaction, enables a rethinking of the technological regulation: from a static formal document it becomes a highly effective, proactive tool for incident prevention and loss minimization at oil refining facilities.

5. Conclusion

Technological regulations have historically served and continue to serve as a basic element of the industrial safety architecture in oil refining. However, under the conditions of increased dynamics of production processes and intensive digital transformation of the industry, the traditional, essentially static, approach to managing this documentation is turning from a protective barrier into an independent source of elevated risk.

Within the framework of the conducted study, all the stated objectives were consistently addressed.

First, an in-depth analysis of the role of static TP and their inherent limitations has been carried out. It has been shown that the traditional regulation functions predominantly as a passive barrier, subject to process drift and to the formation of a gap between work-as-prescribed and work-as-performed.

Second, the influence of digitalization processes on the evolution of regulation management has been investigated. It has been substantiated that modern digital solutions automated process control systems, anomaly detection systems, artificial intelligence tools and digital twins make it possible to move from a reactive, document- and paper-based mode of working with TP to a proactive model based on real-time data analysis and continuous monitoring of process conditions.

Third, the concept of the Living Regulation has been formulated and substantiated. Based on the synthesis of best practices in digital transformation and practical experience in the digitalization and updating of operational documentation, a model of the Living Regulation has been proposed as a new form of existence of TP. This model is interpreted as an integrated cyber-physical system, within which the regulation is subjected to continuous verification and updating through digital platforms, rather than only to periodic paper-based revision. This approach makes it possible, on the one hand, to ensure the stable compliance of TP with the requirements of supervisory authorities, and on the other hand, to turn the regulation into an effective tool for improving operational efficiency, reducing loss levels and proactive risk management at oil refining facilities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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