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**INTEGRATION OF STRUCTURAL AND TECHNOLOGICAL
SOLUTIONS IN INNOVATIVE PROJECTS.
(Fundamental Aspects of the Horizontal and Vertical
Integration of Structural, Engineering, and Technological
Solutions under Conditions of Complex Uncertainty Regarding
the Final Integrated Solution and the Ideal Final Result)**

Vladyslav Drapii ¹

¹ Director of Legarithm OÜ Kyiv, Ukraine

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Abstract

This article examines the growing importance, under conditions of increasingly intensive globalization, of ensuring comprehensive and robust protection of innovative technical ideas against unauthorized appropriation and even direct copying, with particular emphasis on maintaining a degree of non-obviousness of such ideas to an ordinarily skilled specialist within the technological field in which they originate. This issue becomes even more significant as an innovative idea undergoes concrete and comprehensive development and gradually evolves, step by step, from a purely conceptual idea into a set of specific, interrelated technical solutions. This evolution is accompanied by the integrative penetration and technological diffusion of such solutions from one technological field into adjacent fields. A fundamental prerequisite for such cross-field penetration is the shifting of boundaries between technological fields and the progressive blurring of the distinctive characteristics and properties defining those boundaries. As an example of the emergence and synthesis of an innovative idea of this kind, the author presents the development of the concept of non-contact remote control and online monitoring of the parameters and concentrations of a process solution. The initial concept was progressively developed into a sensor-capsule design principle and an algorithm for its application, followed by the serial production of such sensor capsules and their large-scale deployment in modern, complex, high-technology manufacturing environments, as well as their potential application in biotechnology, medicine, and agriculture. At this point, the author considers it necessary to make a brief analytical digression in order to examine macro- and micro-scale scenarios for the development and application of these technologies, taking into account the specific characteristics of applications at different scales and the corresponding differences in operating conditions. Since the author of this article initiates innovative startup projects and

is also engaged in restoring and further developing startup projects in which the **Ideal Final Result** has not been achieved, and, for a number of objective reasons, operates under conditions characterized by a micro-scale technological factor, the article proposes a method for the qualification and comparative analysis of innovative modifications to processes and materials.

Keywords: *Integration of Structural Solutions; Integration of Technological Solutions; Innovative Projects; Fundamental Aspects of Integration; Fundamental Aspects of Horizontal Integration; Fundamental Aspects of Vertical Integration; Final Integrated Solution; Complex Uncertainty Regarding the Feasibility of the Final Integrated Solution; Complex Uncertainty Regarding the Ideal Final Result; Comprehensive Protection of Innovative Technical Ideas; Comprehensive Development of an Idea and Its Gradual, Step-by-Step Transformation from a Concept into Specific Technical Solutions*

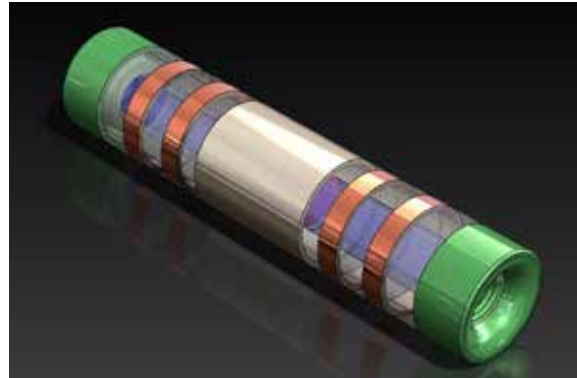
Introduction

In the context of increasingly intensive globalization, ensuring comprehensive and robust protection of innovative technical ideas against unauthorized appropriation and even direct copying has become critically important. In this regard, the non-obviousness of an idea to a person of ordinary skill in the technological field in which the idea originated is of particular significance. This issue becomes even more important as an innovative idea undergoes concrete and comprehensive development and gradually evolves, step by step, from a purely conceptual idea into a set of specific, interrelated technical solutions. This evolution is accompanied by the integrative penetration and technological diffusion of such solutions from one technological field into adjacent technological fields. A fundamental prerequisite for such penetration is the shifting of boundaries between technological fields and the progressive blurring of the distinctive characteristics and properties defining those boundaries. As an example of the emergence and synthesis of an innovative idea of this kind, the author presents the development of a concept originating from the idea of non-contact remote control and online monitoring of the parameters and concentrations of a process solution. This concept was progressively developed into a design principle and an application algorithm for a sensor capsule, followed by the serial production of such sensor capsules and their large-scale application in modern, complex, high-technology manufacturing environments, as well as their corresponding application in biotechnology, medicine, and agriculture. At this point, the author considers it appropriate to make a brief analytical

digression in order to examine macro- and micro-scale scenarios for the development and application of these technologies, taking into account the specific characteristics of applications at different scales and the corresponding differences in the conditions under which such technologies are employed.

Since the author of this publication initiates innovative startup projects and is also engaged in the restoration and further development of startup projects in which the Ideal Final Result has not been achieved, and, for a number of objective reasons, operates under conditions characterized by a micro-scale technological factor, a method is proposed for the qualification and comparative analysis of innovative modifications to processes and materials. It is proposed to examine and compare different initial conditions that determine the baseline requirements for identifying and developing new innovations, both in the field of new materials and in the field of innovative technological methods and techniques. Ultimately, these factors determine the economic efficiency, technological and commercial effectiveness, and overall practical viability of the proposed innovations. For comparative purposes, two contrasting cases may be considered: at one extreme, the complex process of restoring, for example, a painting by a medieval artist that constitutes a museum treasure and may even form part of a nation's cultural heritage; and, at the other, the process of milk homogenization under modern industrial production conditions and within a globalized economy. Both processes require online monitoring; however, they are characterized by fundamentally different baseline parameters and conditions for assessing the need

to introduce innovative technical solutions for such monitoring. The principal distinction between these two processes lies in the respective levels of recoverable and irreversible losses that may arise in the event of a loss of control over the operation of monitoring devices. In the event of an accident or process failure in milk production, irreversible losses are quantifiable and subject to clearly defined limits. By contrast, if control over the quality of materials and the techniques used in their preparation is lost during a restoration process, the resulting irreversible material and non-material losses may exceed even the highest anticipated limits. Consequently, for an innovative project to be practically relevant and to generate the required material, commercial, and non-material benefits, the issues associated with the vertical and horizontal integration of an innovative solution – from the initial idea through to mass production – must be addressed with a sufficient degree of universality to ensure that the level of irreversible losses does not exceed the level of recoverable losses. The emergence of the idea and its subsequent innovative synthesis originate in techniques and methods for the active monitoring of liquid parameters in process vessels through the use of so-called control coupons. Such control coupons have a limited service life and must be replaced with new ones once that service life has expired. As a general rule, these elements are placed in the corners of process vessels and baths, where so-called dead zones tend to occur. In these zones, the level of turbulence is substantially lower than in the central regions of the vessels or baths. Typically, a control coupon of this kind contains a chemical reagent that interacts with the solution contained in the process vessel or bath and, under the progressive action of that solution, undergoes a change in mass. When the control coupon is removed, the nature and extent of changes occurring in the solution are determined by weighing its control element and assessing the corresponding change in mass. Clearly, this method does not provide active online monitoring. In this configuration, the control coupon performs the function of passive, periodic monitoring rather than continuous real-time process control.

Figure 1.

The model depicts a module designed for active, non-contact monitoring of the parameters of a controlled fluid flow. The monitored medium may be a mixture, an emulsion, a fluid medium exhibiting compressible properties, an aerosol, or another type of liquid or multiphase medium. Let us consider the principles of horizontal and vertical integration of the fundamental technical solutions underlying a module intended for remote, non-contact monitoring of an object containing one of the above-mentioned types of media, including liquids, aerosols, chemical solutions, and similar media. As a starting point for a comprehensive analysis of the module's distinguishing features, the author proposes examining the design constraints applicable to the module and its constituent systems, particularly those arising from the requirements and limitations established by applicable standards. As a rule, these constraints comprise a set of interrelated parameters, including dimensions, materials and combinations of materials, as well as the fundamental principles governing the module's operating cycle and enabling it to perform its primary functions. One such function is continuous online monitoring – for example, monitoring the acidity (pH) of a cow's gastric fluid. Based on previous experience with modules of this type, it is known that one of the principal challenges is continuous energy supply. Experiments involving the use of conventional chemical power sources in such modules have generally encountered limitations that ultimately required termination of the experiments. This is primarily because the service life and energy capacity of chemical batteries are inherently limited, while the practical possibilities for retrieving and replacing an

implanted or internally deployed module are even more restricted. Accordingly, the key to solving this problem lies primarily in ensuring a continuous and sufficiently reliable energy supply for all measurement, data-processing, and communication functions of the module. Let us now consider the operating environment within the cow's stomach in which the module is located. The gastric environment is generally acidic. If the gastric fluid is assumed to perform, in parallel with its primary biological functions, the additional function of an electrolyte for an integrated electrochemical power source, electrodes may be incorporated into or arranged on the external surfaces of the module housing. Under these conditions, the module housing with its integrated electrodes, while remaining in continuous contact with the acidic gastric fluid, could perform an additional electrochemical function alongside its primary structural and protective functions. In this configuration, the external surface of the module would form a spatially distributed, three-dimensional planar electrochemical cell (or an array of interconnected cells) capable of generating electrical energy for the module's monitoring and communication systems.

Figure 2.

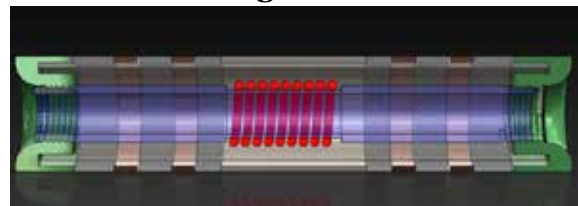


As can be seen in the following figure (3D model), a conductive shield is located at the center of the module's cylindrical structure. This shield provides electromagnetic shielding for the solenoid of the impedance-resonance sensor and is also designed to perform the additional function of one of the electrodes of the proposed innovative electrochemical power source.

Once the problem of electrical power generation is addressed through the use of a continuously replenished resource – namely, the gastric fluid acting as an electrolyte – the same medium can simultaneously perform several interrelated functions within the integrated system. Its acidity parameters are continuously monitored, while the gastric

fluid entering the module's internal channel interacts with structural elements of the module and is subjected to electromagnetic excitation generated by pulses from the sensor solenoid. Under this operating principle, the electrolyte – i.e., the gastric fluid – is exposed to the pulsed electromagnetic field generated by the solenoid sensor, producing a characteristic resonant response. At the peak of the corresponding response pulse, the maximum measured potential difference is obtained and used as an electrical parameter correlated with the acidity (pH) of the gastric fluid at the time of measurement. Simultaneously, along the external surface of the module housing, the same gastric fluid acts as an electrolyte and interacts electrochemically with the electrodes integrated into the module housing in the form of a system of circumferential ring electrodes.

Figure 3.

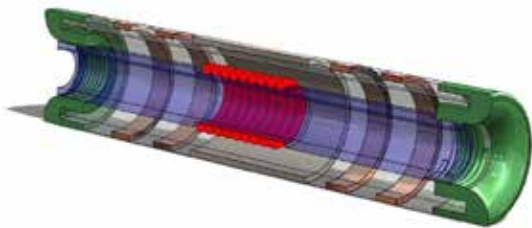


At the same time, these electrodes, in combination with the surrounding volume of electrolyte – the gastric fluid with which they interact – form a combined protective electromagnetic shielding system. This system shields the measurement zone and reduces electromagnetic and electronic noise, thereby improving measurement accuracy in real time. Thus, the module demonstrates a clear integration of functions, providing both horizontal and vertical integration through the continuous functional combination of the module's structural elements and the materials from which those elements are manufactured.

It is precisely this functional integration that constitutes a distinct innovative feature of the proposed technical solution: the same structural elements of the module simultaneously perform multiple functional roles within the overall system. It should be emphasized that all of the combined functions incorporated into the module are implemented using simple geometric configurations, straightforward combinations of structural

materials, and well-established manufacturing techniques that have been repeatedly applied in the fabrication of module prototypes and in the experimental verification of their operating parameters. The simplified geometry of the module's structural elements makes it possible to manufacture a prototype within a relatively short period of time and to conduct comprehensive testing of its operating parameters, as well as to evaluate the efficiency and effectiveness of the complete operating cycle. Figure 1.

Figure 4.

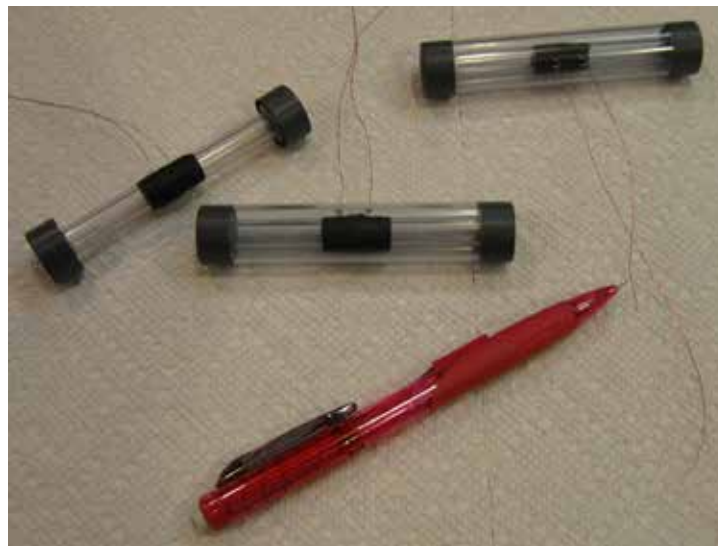


The figure presents a three-dimensional longitudinal sectional model of the module, providing a sufficiently clear representation of the feasibility of implementing the experimental module's vertically and horizontally integrated innovative operating functions.

This level of detailed engineering development of all structural elements of the module makes it possible to fabricate a fully functional experimental prototype incorporating all components and materials required for experimental verification and testing. The following photograph shows full-scale prototypes of the module, fabricated from standard, commercially available materials. The overall dimensions of the module have been established in accordance with the requirements of applicable standards and established requirements for dairy cattle applications. These requirements define dimensional parameters that allow the module to be swallowed by a cow without causing injury or adverse effects associated with its physical dimensions.

Preliminary testing of the modules, conducted under conditions simulating the relevant operating parameters and environment, has demonstrated that the selected materials and their combinations, the methods used to join and assemble the module components, and the specified functional dimensions of its structural elements collectively provide the required level of operational performance and functionality of the module.

Figure 5.



A particularly important aspect of the module development and modeling process was establishing a system-level correlation with the current state of the art in technical and technological equipment used in modern dairy production. The following photographs illustrate a dairy production facility operating at this technological level. Such an

advanced production environment requires a correspondingly high level of technical performance, reliability, and technological compatibility from all equipment components, instruments, auxiliary devices, and tooling employed within the production system. When analyzing the technical and technological level of the commercially manufac-

tured dairy-processing equipment shown in the photographs, it is appropriate to focus specifically on the concept of non-obviousness, considered in conjunction with other

fundamental characteristics of innovation, including novelty at the international level, technical operability, efficiency, and practical utility.

Figure 6.



First of all, it should be noted that the photographs depict standard, commercially manufactured technological equipment used in dairy production in a Western country. The technical and technological level of this equipment, which operates within a closed-loop production process and is controlled by a centralized monitoring and control system, also determines the required performance level of all associated technologies, instrumentation, and monitoring systems. Considering that, even on large-scale commercial dairy farms, an incorrect measurement of the acidity of a single cow's gastric fluid may result in milk of inadequate quality en-

tering the common milk collection system, such an error may subsequently require the affected batch of milk to be excluded from the production and processing cycle, potentially causing significant economic losses to the agricultural enterprise. Consequently, the principal requirements imposed on the proposed module are high operational reliability and the highest practically achievable level of measurement accuracy. If the module developers are able to demonstrate compliance with these stringent requirements, the concept of non-obviousness of the technical solution acquires an additional practical dimension.

Figure 7.



In this context, non-obviousness must be considered not only in terms of the originality of the technical concept itself, but also in relation to the ability of the integrated solution to achieve the required performance under actual operating conditions. Accordingly, the conclusion for the module's designers and engineers is clear: only by demonstrating the required levels of reliability and measurement accuracy can the practical feasibility of implementing this integrated technical solution be established within realistic technological and operational constraints.

Furthermore, the possibility of securing robust patent protection for the entire integrated set of technical solutions embodied, in one form or another, in the module – including its core hardware, software, signal

identification and decoding system, and the algorithms and procedures used to convert the acquired signals into specific quantitative measurement results – together with the demonstrable operability and reliability of all interconnected system components, determines the feasibility of integrating the proposed system into a modern dairy production environment. At the same time, the innovative nature of both the module itself and its associated operational system suggests considerable potential for the application of the module, as well as the integrated technology implemented through its use, across a broad range of industrial and agricultural sectors, and potentially in medicine, biotechnology, and biological research.

Figure 8.



The proposed technology is characterized by the flexibility to modify the design of the module and its principal components. The following models illustrate various design modifications of the module that have made it possible to incorporate a number of additional functional elements without altering its overall external dimensions. These innovations relate, in particular, to the composition, configuration, and geometry of the shielding elements, which simultaneously contribute to the functional characteristics and performance of the integrated electrochemical power source used to supply energy for the measurement process and for trans-

mitting measurement data to the system's central computer. In practical terms, the developments described above may be regarded as an example of the innovative development and refinement of one of the key elements of non-contact measurement technology, as well as the systematic formation of a distinctive combination of technical features characterizing both the technology itself and the devices, software, methods, and systems involved in its implementation. It is the integrated combination of these distinctive technical and system-level features, together with the required level of international novelty, technical operability, practical utility,

and non-obviousness, that can provide a basis for effective intellectual-property and patent protection and thereby help protect these technical solutions against unauthorized appropriation, reproduction, or copying.

Figure 9.

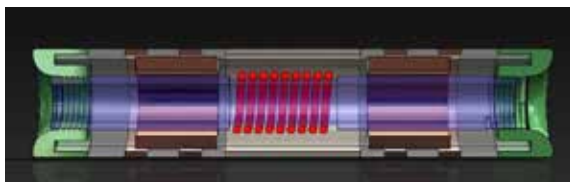


Figure 10.

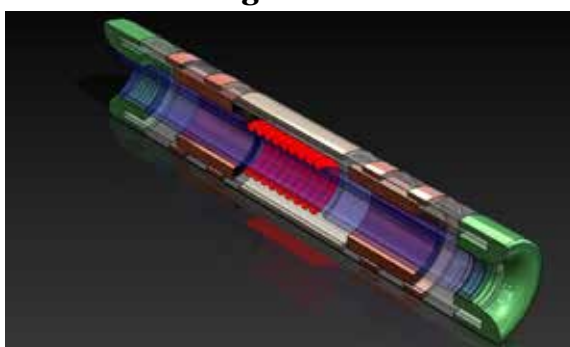


Figure 11.

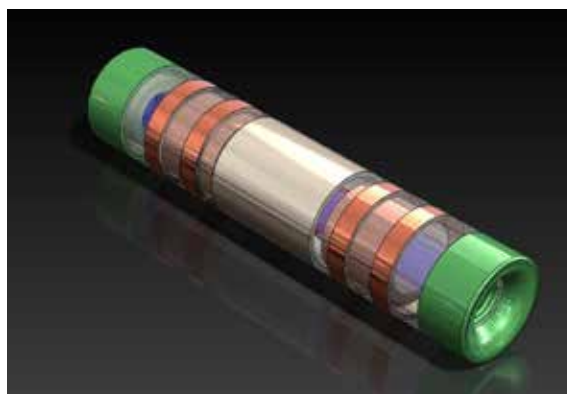
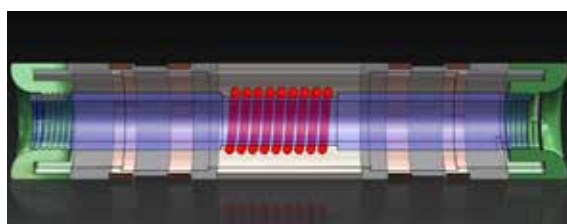


Figure 12.



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© Drapii V.
Contact: vladislavdrapii@gmail.com