MANAGEMENT OF TECHNICAL PREVENTION SYSTEMS IN MANUFACTURING COMPANIES

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Abstract: Technical prevention system management constitutes an important part of work health and safety management systems, in particular in manufacturing companies. Technical resources used within the prevention system should provide for higher level of employee safety and health protection, and proper management of this system should make it possible to effectively and successfully perform actions being taken at all levels within the organisation. This paper presents results of verification of occurrence and nature of interdependence between using technical safety resources and hazards that occur within work environment. The research we have conducted suggests that technical prevention systems are primarily targeted at elimination or restriction of strenuous work hazards in the industrial processing sector.

Key words: prevention system, management, technical measures, occupational hazards

Introduction

Occupational hazard prevention system is part of work health and safety systems being in place in organisations. Approach to performance of preventive actions is compliant with the general approach to the work health and safety management system, i.e. it may take the nature of *ad hoc* actions, systematic actions or systemic solutions (Tabor, 2015), whereas current systemic solutions in the area of providing for safe work environments make use of quality management system approaches and tools (Górny, 2014; Górny 2015).

Occupational hazard prevention systems can comprise various resources, which, due to the way they operate, are defined in the literature as safety barriers (Sklet, 2006). Use of technical resources that provide for collective protection against work environment hazards occupies a key place in the hierarchy of preventive actions in line with regulations being in force (RMPiPS, 2007). Therefore, such resources provide grounds to build successful preventive systems, in particular in manufacturing companies.

Literature Review

Modern prevention concepts are based upon the assumption that accidents result from human presence in dangerous conditions, as well as from unsafe human behaviour, no matter what conditions there are (Tabor, 2013). Several researches, such as Zacheratos et al. (2005), Wallace and Vodanovich (2003) as well as Olton and Głowacki (2014) have suggested that organisation systems have influence on individuals, in particular on safe behaviour. Wallace and Vodanovich (2003)

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suggest that accidents are more likely to happen in automated environments. Brown et al. (2000) and Prussia et al. (2003) studied the interaction between social factors and technical factors at the systems level, focusing mainly on physical safety hazards, work pressure, and perceived safety climate. Vincent et al. (2004) suggest that paying great attention to the design and ergonomic aspects of equipment and implementation of safety devices also has a positive effect on fatigue and cognitive overload of surgeons. Komaki et al. (1980) have studied the impact of worker behaviour on safety and conclude that training and reinforcement help in preventing accidents at work. They also suggest that preventing programs are ineffective without systematic assessment.

Therefore, prevention systems are oriented towards changing surrounding conditions and human behaviours. In this context, activities oriented towards improving human ability to cope with hazards are referred to as relative prevention actions, whereas those that make it impossible to make a dangerous error or those that prevent any undesirable effects of wrong actions from happening are referred to as absolute prevention actions. Activities focused upon conditions – hazards – that recommend making use of technical or organisational safety measures, are referred to as technical prevention or engineering prevention**,** whereas procedures that improve human behaviours are referred to as psychological prevention – behavioral prevention.

Engineering prevention generally adopt an approach called “design for safety” or “integrating safety into design” (Hasan et al., 2003; Pohjola, 2003; Hollnagel, 2004). Most of strategies of engineering intervention include incorporating shields and guards with the equipment, and providing personal protective equipment to the operator. But, design for safety is not always a viable option for existing work-systems. However, if human errors are treated as instances of human-machine or human-task misfit, then frequent instances of misfits are the symptoms of design errors, requiring job redesign (Rasmussen, 1982). Incidents that increase exposure to energy can be modified through job redesign under certain condition (Robertson, 1998). Several studies reported that job redesign and ergonomic interventions lead to improvement in safety, increased job satisfaction and reduction in musculoskeletal disorders (Ferguson et al., 2005; Colombini and Occhipinti, 2006; Torma-Krajewski et al., 2007).

Behavioral prevention generally related to education and training interventions (Whysall et al., 2006; Paul and Mati, 2007, Irimie et al., 2013). Designers of safe behavior programs assume unsafe behavior as the prime cause of accidents, and overlook other casual factors (Hopkins, 2006), but ignore biological limitations. Behavioral preventions can be successful only if they decrease exposure to hazards; do not include components for hazard exposure reduction (Robersson, 1998).

The most popular approach to designing and selecting means in hazard prevention systems is using the ten rules that have been formulated by Haddon in the 80s of the 20th century (Haddon, 1980), whereby, in the first sequence, reduction and elimination of hazards is preferred (technical measures), and then making use of measures that make people resistant to impacts that are exerted by these hazards.

Research Methodology

One of the basic objectives of technical prevention system management is to properly target preventive actions being taken upon hazards that exist in work environment, and to provide for effective and successful completion of actions having been taken. Therefore, we verified occurrence and nature of interdependence between, on one hand, utilisation rates of technical safety resources (TSR) used to eliminate or restrict hazards, and, on the other, coefficients of persons employed in the conditions that pose work environment hazards (WEH), strenuous work hazards (SWH), and mechanical hazards (MH), with respect to which hazards were eliminated or restricted over the year.
As part of our research works:

1. We calculated utilisation rates of technical safety resources used to eliminate or restrict hazards over the years we reviewed;
2. We calculated values of coefficients of persons employed in the conditions that pose three groups of hazards, with respect to which hazards were eliminated or restricted;
3. We calculated Kendall's tau rank correlation coefficients for the adopted initial hypotheses.

We studied 24 industrial processing sector departments over the years 2006-2014, and we paid special attention to the last five years (*Working Conditions*, 2007-2015). For research purposes, we used statistical data gathered and published by the Central Statistical Office based upon the Z-10 form that is employed to examine work conditions. Our studies covered business entities that employed at least 10 persons. The statistical data obtained was processed using the STATISTICA programme in the quantitative and the qualitative aspect. In order to verify interdependence between the adopted variables, we used Kendall's tau rank correlation coefficient from the area of nonparametric tests, as the sample we studied consisted of 24 cases only, and distributions of variables were not normal.
Kendall's tau rank correlation coefficient adopts values in the range (-1;1) and makes it possible to identify both strength and direction of interdependence.
Establishment of occurrence and determination of nature of interdependence between using technical safety resources and a determined group of work environment hazards makes it possible to properly target actions being taken in the area of improvement of technical prevention system management.

Results

As part of the first part of the research, values of examined coefficients were reviewed and calculated. Table 1 illustrates values of coefficients TSR, WEH, SWH, and MH in the industrial processing sector as a whole.

Since values of examined coefficients as listed in Table 1 refer to the industrial processing sector as a whole, they may provide a reference point for a unit analysis of the particular sectors in this section.

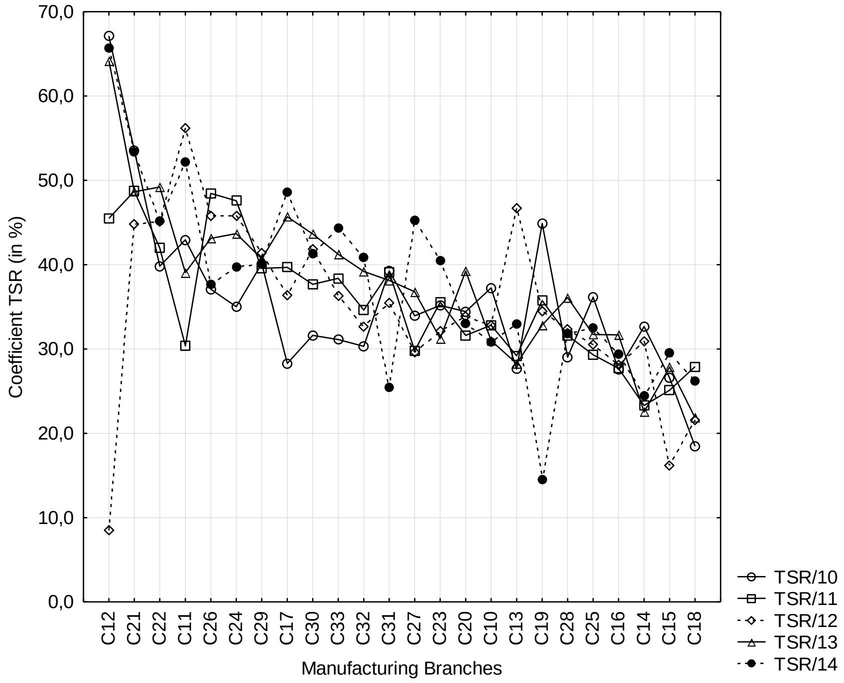
Table 1. Analysis of changes in values of coefficients in the Industrial Processing section *(Author's elaboration based on GUS)*

	2006	2007	2008	2009	2010	2011	2012	2013	2014
TSR (in %)	34.57	34.25	35.02	34.25	35.28	35.16	35.71	37.11	36.63
WEH	42.8	45.3	51.3	50.6	52.3	52.0	51.1	51.4	49.9
SWH	7.8	10.1	12.3	12.7	13.4	11.3	8.8	9.7	7.9
MH	4.9	6.2	7.3	7.9	7.8	7.3	6.6	6.7	5.9

Legend:
TSR – utilization rate of technical safety resources used to eliminate or restrict hazards
WEH – coefficient of persons employed in the conditions that pose work environment hazards, with respect to which hazards were eliminated or restricted,
SWH – coefficient of persons employed in the conditions that pose strenuous work hazards, with respect to which hazards were eliminated or restricted
MH – coefficient of persons employed in conditions that pose mechanical hazards, with respect to which hazards were eliminated or restricted

In order to identify tendencies in changes in variables we examined for the analysed years, profiles of variables were compiled. These profiles made it possible for us to verify the particular sectors in the area of direction of changes in values of variables we examined for the analysed years, i.e. to find out whether the tendencies were growing or falling, as well as in the area of deviations from the median value.
Figure 1 lists utilisation rates of technical safety resources (TSR) used to eliminate or restrict hazards in the particular sectors of the industrial processing sector, from the highest to the lowest median value over the analysed years.

The list suggests that the highest average utilisation rate of technical safety resources (TSR) used to eliminate or restrict hazards was observed in the tobacco products manufacturing sector (C12=50.19) and in the pharmaceutical products manufacturing sector (C21=49.82). High deviations were observed over the analysed years in case of the former sector, while, in the latter sector, utilisation rates of technical resources in the successive years did not undergo such serious changes. At the same time, the lowest average utilisation rate of examined resources was observed in the sector of printing and reproduction of recorded information carriers (C18=23.21), and in the leather and leather products manufacturing sector (C15=25.06).
Figure 2 lists values of coefficients of persons employed in the conditions that pose work environment hazards (WEH), with respect to which hazards were eliminated or restricted, from the highest to the lowest median value of the coefficient over the analysed years.



Notation C according to Polish Classification of Activities (PKD) for Section: Manufacturing

Figure 1. TSR Variable profile *(Author's elaboration based on GUS)*

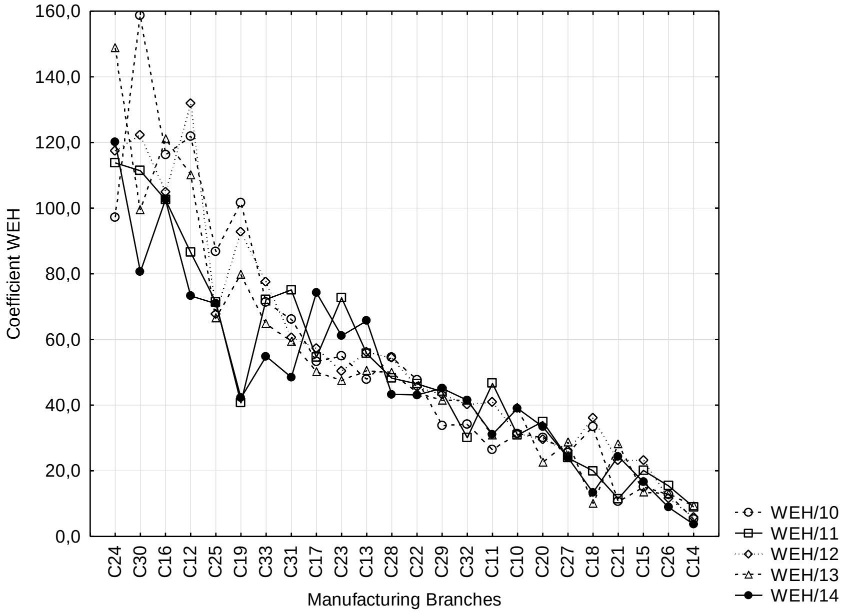


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Figure 2. WEH Variable profile *(Author's elaboration based on GUS)*

The list suggests that the highest median value of the coefficient of persons employed in the conditions that pose work environment hazards (WEH) with respect to which hazards were eliminated or restricted was observed in the metal manufacturing sector (C24=119.5) and in other transport equipment manufacturing sector (C30=114.5), whereas in case of the former sector, a significant increase was observed in the value of the coefficient over the analysed years from 97.2 in 2010 to 120.1 in 2014, while in case of the latter sector – a significant fall was observed in the value – from 158.6 in 2010 to 80.6 in 2014. At the same time, the lowest median value of the WEH coefficient was observed in the clothing manufacturing sector (C14=6.6), and in the computer, electronic and optical products manufacturing sector (C26=12.3).
Figure 3 lists values of coefficients of persons employed in the conditions that pose strenuous work hazards (SWH), with respect to which hazards were eliminated or restricted, from the highest to the lowest median value of the coefficient over the analysed years.

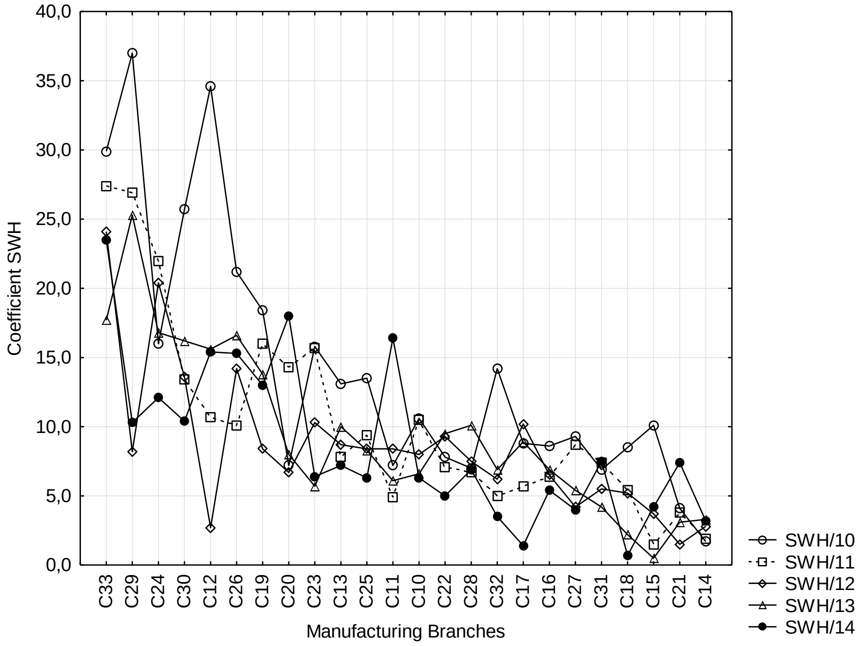

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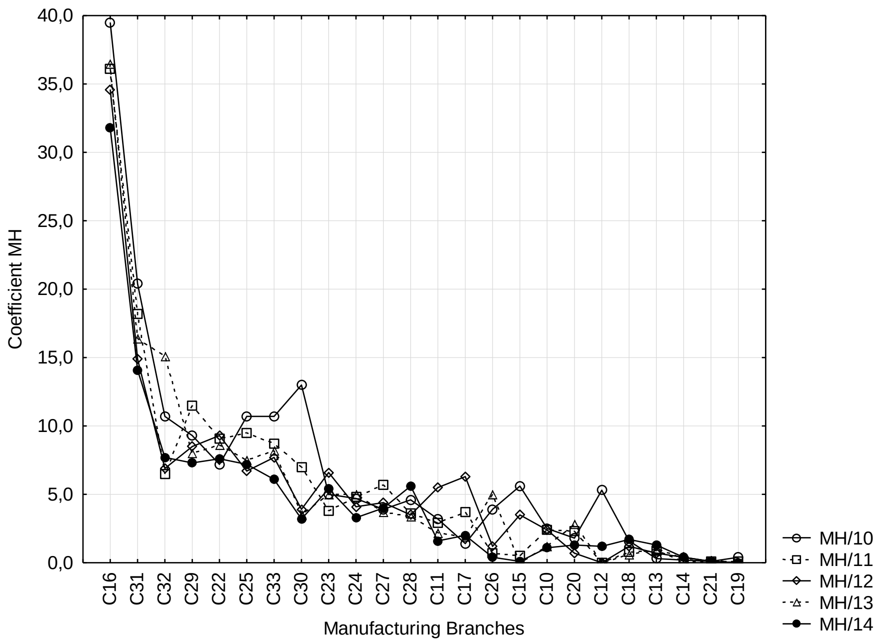
Figure 3. SWH Variable profile *(Author's elaboration based on GUS)*

The list suggests that the highest median value of the coefficient of persons employed in the conditions that pose strenuous work hazards, with respect to which hazards were eliminated or restricted (SWH), was observed in the machinery repair, maintenance and installation sector (C33=24.5), and in the motor vehicle, trailer and semi-trailer manufacturing sector (C29=21.5), whereas in case of the latter sector, a significant fall was observed in the value of the coefficient – from 37.0 in 2010 to 10.3 in 2014 with simultaneous occurrence of high deviations. At the same time, the lowest median value of the SWH coefficient was observed in the clothing manufacturing sector (C14=2.6), and in the pharmaceutical products manufacturing sector (C21=4.0).

Figure 4 lists values of coefficients of persons employed in conditions that pose mechanical hazards (MH), with respect to which hazards were eliminated or restricted, from the highest to the lowest median value of the coefficient over the analysed years.



Notation C according to Polish Classification of Activities (PKD) for Section: Manufacturing

Figure 4. MH Variable profile *(Author's elaboration based on GUS)*

The list suggests that the highest median value of the coefficient of persons employed in conditions that pose mechanical hazards (MH), with respect to which hazards were eliminated or restricted, was observed in the wooden products manufacturing sector (C16=35.7), and in furniture production (C31=16.8), whereas in case of both of these sectors, a fall was observed in the value of the coefficient from 39.5 to 31.8 in sector C16 and from 20.4 to 14.1 in sector C31. At the same time, the lowest value of the MH coefficient was observed in the coke and crude oil refinery products manufacturing sector (C19=0.1), and in the pharmaceutical products manufacturing sector (C21=0.1).

In the second part of our research, we identified and defined the nature of relation between the variables we studied: TSR, WEH, SWH, and MH.

We adopted the following initial hypotheses which assumed that there was no statistically significant interdependence between utilisation rate of technical safety resources and coefficients: H01 - persons employed in the conditions that pose work environment hazards (WEH), H02 - persons employed in the conditions that pose strenuous work hazards (SWH), and H03 - persons employed in the conditions that pose mechanical hazards (MH), with respect to which hazards were eliminated or restricted. Alternative hypotheses assumed that there was a statistically significant interdependence of precise nature that resulted from the Tau value. Table 2 lists results of analysis of nonparametric correlations for the adopted variables TSR, WEH, SWH, and MH.

Table 2. Analysis of correlations between the variables examined

Non-parametric statistics: Tau Correlation of Kendall, N = 24, significant level α = 0.05
X variable: coefficient of persons employed in the conditions of hazards
Y variable: utilization rate of technical safety resources

	Tau	Z	p	Tau	Z	p	Tau	Z	p
Y \ X	WEH			SWH			MH		
TSR/10	0.0217	0.1488	0.8817	0.3593	2.4600	0.0138	-0.0438	-0.2998	0.7643
TSR/11	0.1811	1.2402	0.2149	0.3043	2.0836	0.0371	0.0837	0.5736	0.5662
TSR/12	0.0181	0.1242	0.9011	0.4481	3.0677	0.0021	0.0437	0.2998	0.7643
TSR/13	0.2142	1.4662	0.1426	0.3811	2.6092	0.0091	0.1318	0.9028	0.3661
TSR/14	0.1159	0.7937	0.4273	0.3303	2.2613	0.0237	0.0401	0.2743	0.7838

Tau – T. Kendall coefficient (-1;1) Z – the value of the Z - statistic testing the significance of the T – coefficient; p – the level of probability for Z – statistic

Analysis of materiality levels for Z statistics indicates that there are no grounds to refute our initial hypotheses H01 and H03 over all of the analysed years for WEH and MH variables $p>0.05$. On the other hand, in case of the SWH variable, the initial hypothesis can be refuted due to the fact that $p<0.05$. Hence, utilisation rate of technical safety resources shows a statistically significant correlation with the value of coefficients of persons employed in the conditions that pose strenuous work hazards over all of the analysed years. Furthermore, Tau values indicate that there is a positive correlation, which means that the increase in the utilisation rate of technical safety resources used to eliminate or restrict hazards is connected with the increase in the value of the coefficient of persons employed in the conditions that pose the strenuous work hazard, with respect to which hazards were eliminated or restricted.

Conclusion

The research we have conducted suggests that in the industrial processing sector technical prevention systems are chiefly targeted at elimination or restriction of strenuous work hazards, i.e. excessive physical strain, insufficient lighting of workstands, forced position of the body, or monotony of work.

Hazards of this type are eliminated or restricted through mechanisation or automation of work, additional protective facilities in the form of various protective covers, additional lighting of workstands, effective local ventilation systems, air-tight separation of technological processes, etc.

Companies use various preventive measures to eliminate or restrict their work environment hazards. In fact, not all solutions that researchers propose are used, which may result from a number of very different reasons. Companies primarily tend to act in compliance with regulations being in force in this area, which oblige them to take some determined actions in case some determined hazards occur. Another very important issue is costs of preventive actions, which may be very varied in nature, and their spread over time can make it difficult to assess preventive actions being taken for their effectiveness. Some resources, if used, also result in some effects for the employee, on one hand by providing for his/ her safety at work, and on the other, by making it difficult for him/ her to meet his/ her productivity rates, or even by lowering them. From the point of view of their scope of operation, technical collective protection measures are preferred to personal protection measures, while from the standpoint of durability – technical resources are preferred to behavioural resources. Based upon these exemplary criteria, it is possible to select some determined technical safety resources in order to build a prevention system that would be appropriate for the conditions of a given company. This, however, does not guarantee proper operation of the system, as any technical prevention system also includes the human factor which is responsible for proper operation of the system, i.e. for effective usage of resources held.

Conclusions resulting from the research we have carried out are only important for companies that employ more than 10 persons, i.e. they do not refer to the group of employers, which is quite vast and specific from the point of view of work health and safety management. Therefore, it would be advisable to conduct some further research in the industrial processing sector, primarily in the group of micro-companies that employ up to 10 persons. Furthermore, it would be advisable to identify the nature of actions being taken in the area of technical prevention, whether systematic or systemic, and to identify the degree of implemented solutions' compliance with the general approach to work safety management in manufacturing companies from different sectors.

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ZARZĄDZANIE SYSTEMAMI PROFILAKTYKI TECHNICZNEJ W PRZEDSIĘBIORSTWACH WYTWÓRCZYCH

Streszczenie: Zarządzanie systemem profilaktyki technicznej stanowi istotną część systemu zarządzania bezpieczeństwem i higieną pracy, szczególnie w przedsiębiorstwach wytwórczych. Stosowane w systemie profilaktyki środki techniczne powinny zapewnić zwiększenie poziomu bezpieczeństwa i ochrony zdrowia pracowników a zarządzanie tym systemem powinno umożliwić sprawną i skuteczną realizację podjętych działań na wszystkich poziomach organizacyjnych. W artykule zaprezentowano wyniki weryfikacji istnienia i charakteru zależności między stosowaniem technicznych środków bezpieczeństwa a występującymi w środowisku pracy zagrożeniami. Z przeprowadzonych badań wynika, że w przetwórstwie przemysłowym systemy profilaktyki technicznej ukierunkowane są przede wszystkim na eliminację lub ograniczenie zagrożeń związanych z uciążliwością pracy.

Słowa kluczowe: prevention system, management, technical measures, occupational hazards

技術防範系統的管理製造型企業

摘要：技術防範系統的管理工作，構成健康和安全管理體系的重要組成部分，特別是在製造企業。預防系統內使用的應為員工的安全和健康保護，而這個系統的適當管理的更高層次的技術資源，應能有效地和成功地執行所採取的組織內各級採取行動。本文提出核查的發生和使用安全技術資源，並在工作環境中發生的危險之間的相互依存的自然結果。我們所進行的研究表明，技術防範系統主要針對消除在工業加工部門的艱苦努力危害或限制。

關鍵詞：預防體系，管理，技術措施，職業危害