

นิพนธ์ต้นฉบับ

(Original article)

Design of dry chemical fire extinguisher inspection equipment in order to reduce ergonomic risks for fire extinguisher inspectors

การออกแบบอุปกรณ์ตรวจสอบถังดับเพลิงเคมีแห้งเพื่อลดความเสี่ยง ด้านการยศาสตร์ ของผู้ตรวจสอบถังดับเพลิง

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ABSTRACT: It is important that a dry chemical fire extinguisher must be inspected for its readiness. For each inspection, the inspector needs to turn the fire extinguisher tank upside down to let the chemical inside the tank move and prevent solidification which would make the tank not ready for usage when needed. Each tank weighs approximately 12.9 kg. The inspector has to turn each tank upside down twice (2 minutes/round). He needs to turn it over the shoulder close to his ear in order to hear the chemical flow inside, or use his hands to feel the moving from the outer surface of the tank. The survey and questionnaire “The Questionnaire Know Body” which includes neck (left and right sides), both shoulders, upper and lower right arms suggest that all 12 security staff suffer from the same fatigue. The current dry chemical fire extinguisher inspection affects various ergonomic health problems. Rapid Entire Body Assessment (REBA) is used for evaluation of postural risks so that the working postures may be redesigned or corrected. The dry chemical fire extinguisher inspection equipment has been developed to reduce ergonomic health risks for the inspectors. A REBA analysis has been performed again, and the risk score has decreased from 13 to 3. In addition, feedback from the first trial of the developed equipment shows that there are demands to increase installation of this new equipment. The installation requires three main parts. The wall attachment secures the tank tightly with the wall, supporting the entire weight of the tank without manual lifting needed. This reduces exertion on the wrists and arms while checking the tank. This wall attachment is suitable for both hands. The tank support standee is used for convenient tank rotation with very small pushing force. The locking bar locks the tank in place while turning it over.

Keywords: Dry chemical fire extinguisher inspection equipment; Ergonomics; Rapid Entire Body Assessment

บทคัดย่อ: ถังดับเพลิงชนิดผงเคมีแห้งจำเป็นต้องตรวจสอบความพร้อมการใช้งาน โดยในแต่ละครั้งพนักงานตรวจสอบต้องทำการยกพลิกกลับถังทุกครั้ง เพื่อให้สารเคมีในตัวถังเคลื่อนตัว ป้องกันการจับตัวเป็นก้อน ซึ่งทำให้ไม่สามารถใช้งานได้เมื่อเกิดเหตุเพลิงไหม้ ถังดับเพลิงมีน้ำหนักประมาณ 12.9 กิโลกรัม การตรวจสอบโดยยกพลิกกลับถัง 2 ครั้งเป็นเวลา 2 นาที/ครั้ง/ถัง มีท่าทางการยกพลิกกลับถังขึ้นเหนือไหล่ แขนหูเพื่อฟังการไหลของสารเคมีภายในถังหรือใช้ฝ่ามือสัมผัสเพื่อรับทราบการไหลของสารเคมีภายในถัง จากแบบสำรวจและสอบถาม “The Questionnaire Know Body” ในสัดส่วนคอ และไหล่ ด้านซ้ายรวมถึงคอ ไหล่ แขนท่อนบน และแขนท่อนล่างด้านขวาพบความเมื่อยล้าของพนักงานรักษาความปลอดภัย 12 คนเป็นไปในทิศทางเดียวกัน ผลกระทบจากการตรวจสอบถังดับเพลิงเป็นปัญหาสุขภาพทางด้านการยศาสตร์ จึงประเมินความเสี่ยงท่าทางโดยวิธี Rapid Entire Body Assessment (REBA) พร้อมนำผลการประเมินความเสี่ยงมาพิจารณาออกแบบปรับปรุงและแก้ไขท่าทางการทำงาน ได้ “อุปกรณ์ตรวจสอบถังดับเพลิงเคมีแห้ง” เพื่อลดความเสี่ยงด้านการยศาสตร์ของผู้ตรวจสอบถังดับเพลิงทดลองใช้งานและประเมินความเสี่ยงโดย REBA ซ้ำหลังการปรับปรุงมีผลจาก Risk score 13 เหลือเพียง 3 รวมถึงผลตอบรับในการทดลองใช้งาน ปรากฏว่ามีความต้องการขยายผลในการติดตั้งอุปกรณ์ใหม่นี้เพิ่มขึ้น ในการติดตั้งอุปกรณ์ใหม่นี้ประกอบไปด้วย 3 ส่วนหลัก อุปกรณ์ที่ยึดติดกับผนังช่วยยึดถังให้แน่นกับผนัง รองรับน้ำหนักทั้งหมดของถังโดยไม่ต้องยกถังด้วยมือ ซึ่งจะช่วยลดการออกแรงที่ข้อมือและแขนขณะตรวจสอบถัง อุปกรณ์ที่ยึดติดกับผนังนี้เหมาะสำหรับการใช้งานได้ทั้งมือซ้ายหรือมือขวา แท่นรองรับถังใช้สำหรับการหมุนถังได้อย่างสะดวกโดยใช้แรงที่น้อยมาก ส่วนที่ล็อกตัวถังจะยึดถังให้อยู่กับที่ขณะพลิกถัง

คำสำคัญ: อุปกรณ์ตรวจสอบถังดับเพลิงเคมีแห้ง; การยศาสตร์; แบบประเมินแบบรวดเร็วทั้งร่างกาย

1. INTRODUCTION

Fire prevention is significant for the sustainability of businesses, including those which involve animal feeding production. A fire is often costly, affecting lives of employees, damage to assets and the surrounding environment, as well as the company's reputation. Therefore, fire protection management is needed, and periodic checkups are required for all related installed equipment to be able to respond immediately to a possible emergency. A fire extinguisher, one of the basic equipment used to extinguish a small fire, needs to be inspected regularly, according to the standards and regulations of equipment inspection. A dry chemical fire extinguisher must be frequently checked for readiness for usage of the content inside. The inspection procedure is a risky activity, physically, chemically, biologically, and most importantly ergonomically. The risk report from the safety committee in this study shows that the inspectors have a high ergonomic risk. Their working postures at risk include holding an extinguisher tank and flipping it upside down to check whether the dry chemical inside is becoming solidified (Fig. 1). This causes fatigue, irritation and musculoskeletal structure pain.



Fig. 1 Dry chemical fire extinguisher inspection postures

Statistical data have been obtained from the first-aid room attendance report of an animal feed factory in Chonburi, Thailand, and analyzed with additional information from a specific group of 12 security staff who undertake dry chemical fire extinguisher inspection. The identified ergonomic risks are ordered according to their importance. Then, a new design of the inspection equipment is developed to reduce ergonomic problems. Furthermore, some advice for safe working environment and sustainability is provided.

In 2019, the first-aid room visiting data indicate that 38 out of 59 cases (64.4%) concerning with work-related pains and musculoskeletal structure problems are the staff from the security department. Additionally, "The Questionnaire Know Body"¹ survey shows similar fatigue on the neck, shoulders, upper and lower right arms on 12 of the security staff². Thus, this research aims at an ergonomic design of a dry chemical fire extinguisher inspection equipment to solve the problem of inappropriate postures in order to reduce the rates of injury and symptoms associated

with the musculoskeletal structure. Moreover, this innovation in safety engineering may enhance the employees' quality of life.

2. METHODS

To understand this research thoroughly, the authors have reviewed other related literature for important knowledge necessary for the study. Furthermore, the task procedure performed by the 12 security personnel who are responsible for dry chemical fire extinguisher inspection has been obtained to evaluate related ergonomic risks in order to design the study method and research procedure (Fig. 2).

**Method The Design of Dry Chemical Fire Extinguisher Inspection Equipment
In order to Reduce the Ergonomical Risks of Fire Extinguisher Inspectors**

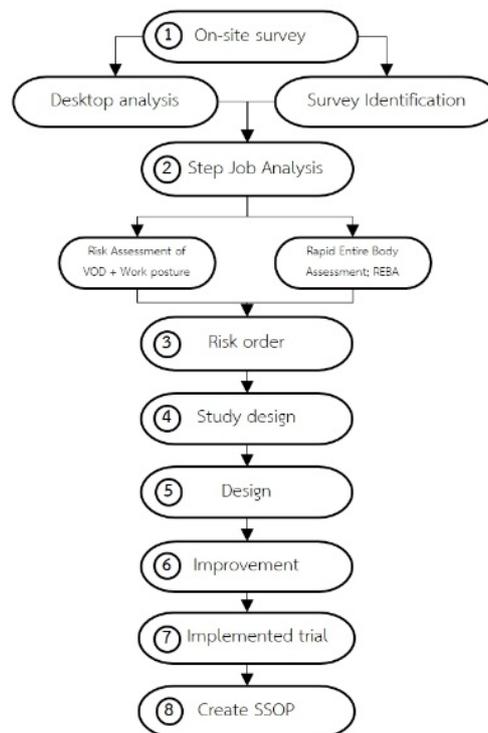


Fig. 2 Study method and research process of designing dry chemical fire extinguisher inspection equipment to reduce ergonomic risks

2.1 This research starts with an on-site survey of the security inspection activity (Job Analysis)³ with two criteria evaluated:

2.1.1 Desktop Analysis⁴ This evaluates recorded information about ergonomic risks, degree of awareness of employee's health, the trend of first-aid service and room usage, and solution for recognized petitions. The procedure includes: 1) Floor plan of the factory's dry chemical fire extinguisher placement, 2) Staff at risk and their annual health checkup, 3) First-aid room service statistics, and 4) Monthly security meeting report.

2.1.2 Survey Identification: Ergonomic risks are observed and evaluated by the team leader or a security expert in human factors using the following methods: 1) Recorded video of work procedure, 2) Evaluation of interview or questionnaire on work-related pain or injury, 3) Risk assessment on security of occupational health at work, and 4) Risk assessment on personal health⁴.

2.2 The initial procedures above provide a clear studying scope of risks for this research. With experiences in the work and innovative development related to ergonomics, the researchers have organized a procedure called Step Job Analysis consisting⁵ of:

2.2.1 If an important problem is found, related ergonomic statistics or health examination report must be organized and evaluated to apply a risk management plan.

2.2.2 The information indicated by animated operation and survey is used to analyze the portion of task and related working posture, and identify the effects caused by the main procedure. Then, the risks must be evaluated orderly to apply a risk management plan.

2.2.3 If the evaluation using all the above information and risk index from the survey is found relevant with the research problem, an ergonomic assessment tool is chosen. Rapid Entire Body Assessment (REBA) has been used in this research on all the 12 security personnel (100%) who perform dry chemical fire extinguisher inspection to evaluate related ergonomic risks and apply a risk management plan accordingly. The dry chemical fire extinguisher inspection procedure consists of 6 postures. The risk assessment results are shown in Table 1.

2.2.4 If the analysis of the recorded interview or survey on fatigue and injury clearly indicates work-related risks, the risks must be evaluated for a risk management plan.

2.3 The next step is using the result obtained previously together with the overall operational procedure evaluations to arrange the risks in order before proceeding to the working plan as presented to the responsible authority.

2.4 For the study on ergonomic effects and problems for a new design, this research clearly shows the workstation and environment without any pre-existing risk by considering the design steps in⁶.

2.5 The following four principles are used for a new design to reduce risks and come up with resolution⁷:

2.5.1 Using TRIZ 40 Principle⁸ or creative innovation to guide the design.

2.5.2 Revising the design using body portion method with connection and tolerance to support physical actions of humans.

2.5.3 Searching for an existing prototype or substance to guide the development of ideas together with the problem and come up with safe procedures or workstation.

2.5.4 Negative consequences in every designing step, such as reduced productivity, more time-consuming, and especially any new risk, need to be considered.

Table 1 REBA risk assessment result before adjustments

The REBA Score for postures of dry chemical fire extinguisher inspection						
	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
The whole body is moving.						
Neck	3	3	3	3	2	1
Trunk	2	2	3	4	4	3
Leg	3	2	2	2	3	3
Force/Load	2	2	2	2	2	2
Upper Arm	2	3	3	4	2	3
Lower Arm	2	2	2	2	2	2
Wrist	2	2	2	2	2	2
Coupling	1	1	1	1	1	1
Move/Activity	2	2	2	2	2	2
REBA Score	11	11	12	13	12	11
Risk Level	Very High	Very High	Very High	Very High	Very High	Very High
Frequency	Act often	Act often	Act often	Act often	Act often	Act often

2.6 The next step is improvement with the best process by considering cutting off the problem and creating automation to get rid of any possible risks. Then, the improvement needs to be evaluated.

2.7 The decision may not be implemented automatically due to some constraints, such as procedure improvement budget, automatic design theory, available resources, and designing experts. In this case, reducing risk exposure will be considered. Although a risk score may not reach the minimum point, a low risk level is often adequate.

2.8 Finally, a work safety standard (SSOP) that leads to safe routine work completion with a clear systematic operation is created. This requires the participation of engineers, safety and health engineering experts, ergonomists, staff and unit managers to approve the work standard.

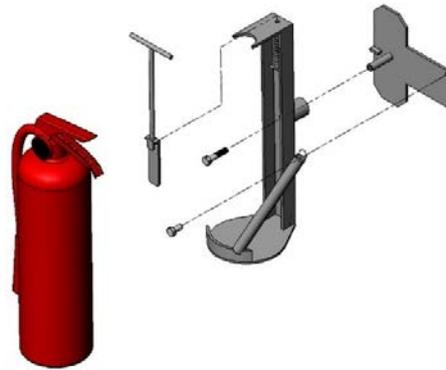


Fig. 4 Dry chemical fire extinguisher inspection equipment

Table 2 REBA risk assessment result after adjustments

The REBA Score for postures of dry chemical fire extinguisher inspection				
	Position 1	Position 2	Position 3	Position 4
The whole body is moving.				
Neck	1	1	1	1
Trunk	2	2	2	2
Leg	1	1	1	1
Force/Load	0	0	0	0
Upper Arm	2	2	2	2
Lower Arm	1	1	1	1
Wrist	2	2	2	2
Coupling	0	0	0	0
Move/Activity	2	2	2	2
REBA Score	3	3	3	3
Risk Level	Low	Low	Low	Low
Frequency	Act often	Act often	Act often	Act often

The new device eliminates ergonomic risks during fire extinguisher inspection. The wall attachment secures the tank tightly with the wall, supporting the entire weight of the tank without manual lifting needed. This reduces exertion on the wrists and arms while checking the tank. This

wall attachment is suitable for either left-handed or right-handed inspectors. The tank support standee is used for convenient tank rotation with very small pushing force needed. The locking bar secures the tank in place while turning it over. These equipment parts are illustrated in Fig. 4. During tank inspection, while rotating the tank, the inspector can touch the tank surface to feel the moving dry chemical contained inside without having to listen to its sound. The experiment using the newly designed inspection equipment gives a low REBA score of 3 for all the positions 1 to 4 (Table 2). In comparison with another similar research about rotating a dry chemical portable fire extinguisher⁹, this new equipment is more convenient than the design on that study because no additional tools are required, and the steps for inspection have been reduced.

4. CONCLUSION

The design of dry chemical fire extinguisher inspection has been supported by the factory and inspectors. The improvement of working postures from six steps (Fig. 5) to only four steps (Fig. 6) has resulted in significant reduction of ergonomic risk. Even though the risk score cannot decrease to one, a score of three is low enough to let the employees work with a small risk, not having to raise the tank over the shoulder for inspection. In addition, training to give knowledge about working ergonomically is needed to make the employees aware of work safety.



Fig. 5 The six postures of dry chemical fire extinguisher inspection

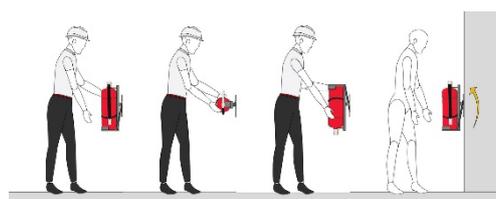


Fig. 6 The four postures of dry chemical fire extinguisher inspection

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