DESIGN OF DRY CHEMICAL FIRE EXTINGUISHER INSPECTION EQUIPMENTIN ORDER TO REDUCEERGONOMIC RISKS FOR FIREEXTINGUISHER INSPECTORS

[1]SITRAPEE CHANGMUENWAI, [2]SUDARATANA WONGWERAGIAT

[1]Safety Engineering Faculty of Engineering Kasetsart University, Thailand
[2]Ph.D, Industrial Engineering Faculty of Engineering Kasetsart University, Thailand
E-mail: [1]safetyprg@gmail.com, [2]suewongweragiat@gmail.com

Abstract - It is important that a dry chemical fire extinguisher must be inspected for its readiness. For each inspection, the inspectors need 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 16 kg. The inspectors have to turn each tank upside down twice (2 minutes/round). They need to put the tanks over their shoulder close to their ear in order to hear the chemical flow inside the tank, or use their hands to feel it. According to an investigation of 146 tanks and the statistical report from the first-aid room in 2019, those who visited the room for first-aid services related with skeletal or muscular injuries were mostly the security staffs from the Security Administration Department (38 out of 59 times or 64.4%). The survey and questionnaire "The Questionnaire Know Body" which includes neck, left shoulder, upper and lower right arms suggest that all 12 security staffs have the same fatigues. The current dry chemical fire extinguisher inspection affects various ergonomic health problems(Radin Umar, Ahmad, Halim, Lee, & Hamid, 2019). Rapid Entire Body Assessment (REBA)(Lee et al., 2015) is used for evaluation of posture 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 been decreased from 13 to 3. In addition, feedbacks from the first trial of the newly developed equipment show that there are demands to increase the installation in order to reduce the ergonomic health risks(Edwards & Winkel, 2020).

Keywords - Dry chemical fire extinguisher inspection equipment, Ergonomic, Rapid Entire Body Assessment; REBA

I. INTRODUCTION

Fire prevention is significant for sustainability of businesses, including those which involve animal feeding production. A fire is often costly, affecting employees' life, damage on assets and surrounding environment, as well as company's reputation. Therefore, fire protection management is needed, and periodic check-up is required for all related installed equipment to be able to respond immediately to a possible emergency.A fire extinguisher, a basic equipment to extinguish a small fire, needs to be inspected regularly, according to the standard and regulation of equipment inspection. Adry chemical fire extinguisher must be frequently checked for its readiness of the content inside when in use. The inspection procedure is a risky activity, physically, chemically, biologically and ergonomically. The risk assessment in this research 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. This causes fatigue, irritation and musculoskeletal structure pain (figure 1).

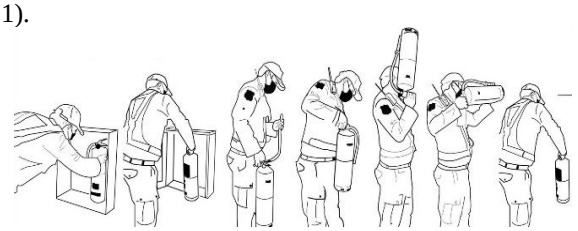


Figure 1 Dry chemical fire extinguisher inspection posture

Thus, this research aims at an ergonomic design of a dry chemical fire extinguisher inspection equipment to solve the problem of the inappropriate postures in order to reduce the rates of injury and symptoms on musculoskeletal structure. Moreover, this new innovation in safety engineering may enhance the employees' quality of life.

Statistical data (figure 2) has been obtained from the first-aid room attendance report of an animal feed factory in Chonburi, Thailand, and analyzedwith additional information from a specific population of 12 security staff who work with dry chemical fire extinguisher inspection.

The identified ergonomic risks are ordered according to importance. Then, a new design of the inspection equipment is developedto reduce ergonomic problems. Furthermore, some advice for safe working environment and sustainability is provided.

In 2019, the attendance data from the first-aid room concerning with problems of work-related pain and musculoskeletal structure indicates that 38 out of 59 cases (64.4%) are the staff from the security department.

Additionally, "The Questionnaire Know Body" (figure 3 and 4)(Serratos-Perez, Hernandez-Arellano, & Negrete-Garcia, 2015)survey shows similar fatigue onthe neck, left shoulder, upper arm and right lower arm on 12 of the security staff.

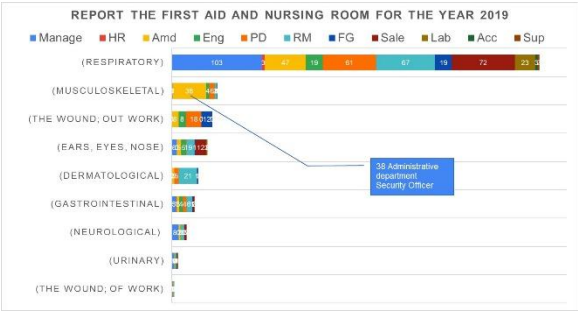


Figure 2 Statistic report of first-aid room service grouped by symptom and department (Jan-Dec 2019)

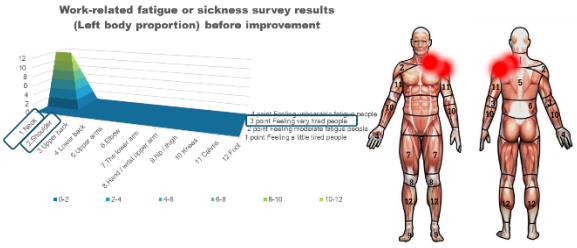


Figure 3 Survey and questionnaire result (Left) "The Questionnaire Know Body"

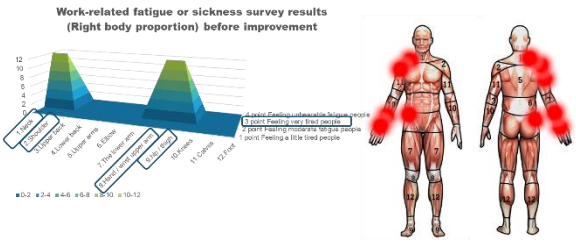


Figure 4 Survey and questionnaire result (Right) "The Questionnaire Know Body"

II. DETAILED EXPERIMENTAL AND RESEARCH METHODS

To understand this research thoroughly, the researchers have closely revised and organized other studiesfor appropriate applications in order to design the method and research procedure(figure 6).

2.1. This research starts with an on-site survey of security inspection activity (Job Analysis)(Handbook, 1974) with 2 criteria evaluated:

2.1.1 Desktop Analysis(Hassim & Edwards, 2006) – 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 factory's dry chemical fire extinguisher placement 2)Staff at risk and their annual health check-up 3) First-aid room service statistics 4) Monthly security meeting report.

2.1.2 Survey Identification – Ergonomic risksare 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 4) Risk assessment on personal health(Hassim & Edwards, 2006).

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 researchershave organized a procedure called Step Job Analysis consisting(Enez & Nalbantoğlu, 2019) of:

2.2.1 If an important problem is found, related ergonomic statistics or health check-up 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 evaluate the portion and posture of the work, 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 usingall 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 to identify the procedure affecting the work operation, and evaluate related risks accordingly to apply a risk management plan.

2.2.4. If analysis of the recorded interview or survey on fatigueand injuryclearly indicateswork-related risks,the risks must be evaluated for a risk management plan (figure 5).

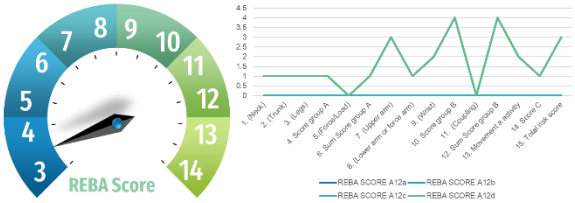


Figure 5 REBA risk assessment result before adjustments

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

2.4. For the study on ergonomic effects and problems for a new design, this research clearly shows the work station and environment without any pre-existing risk by considering the design steps in 2.5 below.

2.5. The following 4 principles are used for anew design to reduce risks and come up with resolution.

2.5.1 Using TRIZ 40 Principle(Li, Ming, Zheng, He, & Xu, 2015) 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 existingprototype or substance to guide the development of ideas together with the problem and come up with safe procedure or work station.

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

2.6. 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 beimplemented automatically due to someconstraints, 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 0 (out of 10),a low risk level (5 or less, or nearly 0) is often adequate.

2.8. Next step is to create work safety standard (SSOP) that leads tosafe routine work completion with clear systematic operation. This requires participation of engineers, safety and health engineering experts, ergonomists, staff and unit manager to approve the work standard.

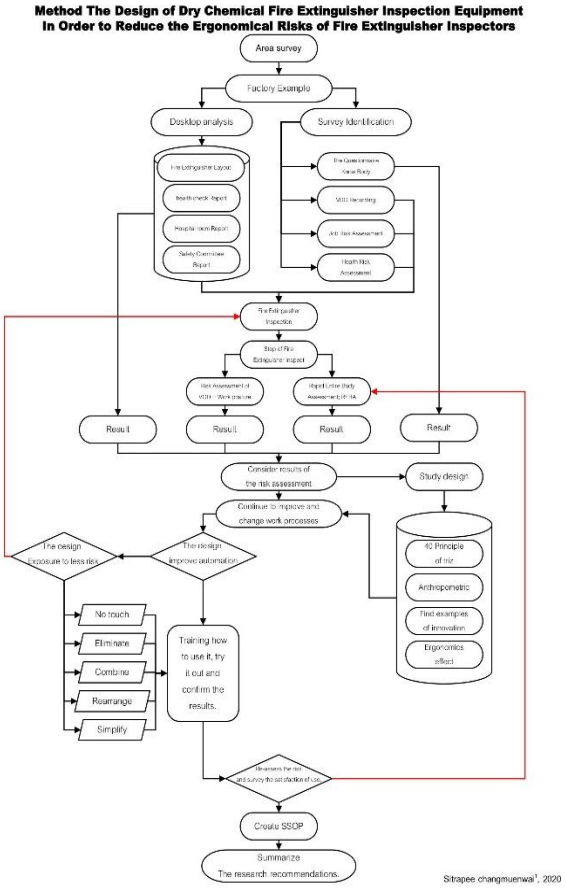


Figure 6 Study method and research process of designing dry chemical fire extinguisher inspection equipment to reduce ergonomic risks

III. RESULTS AND DISCUSSION

The risk assessment for the dry chemical fire extinguisher inspection resulted from REBA analysis shows a high risk score of 13. The inspection process has beenimproved with a new design of the inspection equipment (Figure 10) in order to reduce risks from the work postures causing body fatigue or pain.The new design also includes the wall attachment(Figure 7), tank support standee(Figure 8)andfire extinguisher locking bar (Figure 9).The inspector may rotate the tank while inspecting it. The experiment using the newly designed inspection equipment gives a low REBA score(Figure 11).

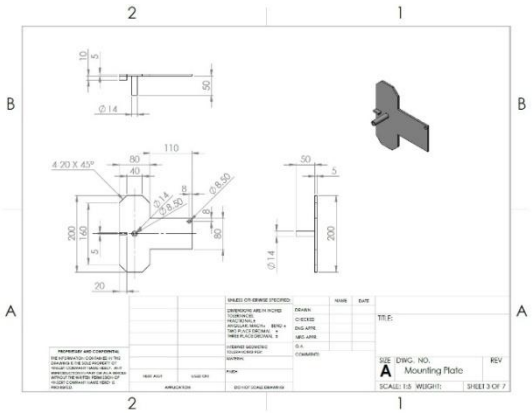


Figure 7 Wall attachment

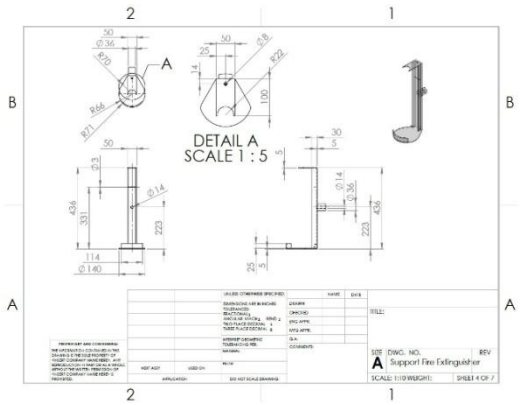


Figure 8 Tank support standee

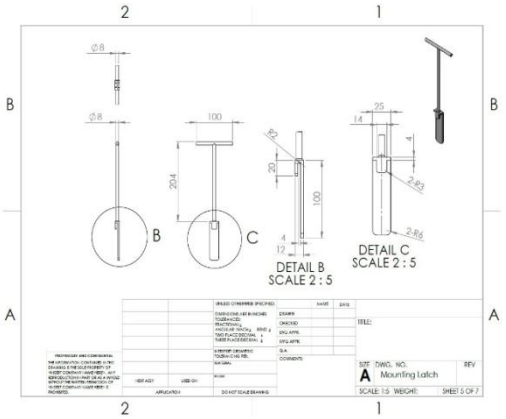


Figure 9 Fire extinguisher locking bar

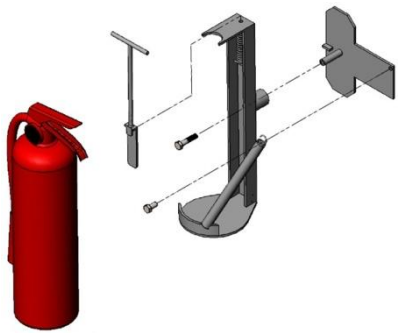


Figure 10 Dry chemical fire extinguisher inspection equipment

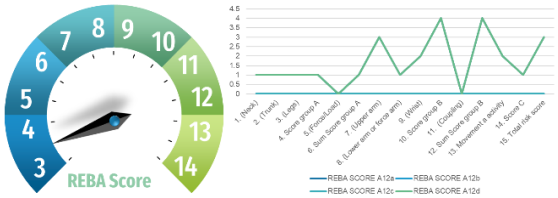


Figure 11 REBA risk assessment result after adjustments

IV. CONCLUSION

The design of dry chemical fire extinguishers inspection has been supported by the factory and inspectors. The improvement of working postures from 6 steps(Figure 12)to 3 steps(Figure 13)has resulted in considerable risk reduction. Even though the risk score cannot decrease to 0, 3 is low enough to let the employees work with a small risk, not having to raisethe 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.

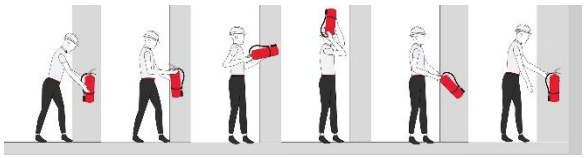


Figure 12 6 postures of dry chemical fire extinguisher inspection



Figure 13 3 postures of dry chemical fire extinguisher inspection

ACKNOWLEDGMENTS

The achievement of this research has been greatly supported by the management team, the Occupational Safety, Health and Engineering Department at CPF (Thailand) Public Company Limited, Sriracha Livestock Feed Plant, Chonburi, Thailand for the budget,the experimental population, and all necessary information about the working environment, and the actual application of the designed equipment.

Most importantly, we would like to thank the faculty members of the Safety Engineering and the Industrial Engineering departments at Kasetsart University for providing technical knowledge and monitoring the completion ofthis research.

REFERENCES

[1] Edwards, K., & Winkel, J. (2020). Corrigendum to "A method for effect modifier assessment (EMA) in ergonomic intervention research" [Appl. Ergon. 72C (2018) 113-120]. Appl Ergon, 84, 103004. doi:10.1016/j.apergo.2019.103004

[2] Enez, K., & Nalbantoğlu, S. S. (2019). Comparison of ergonomic risk assessment outputs from OWAS and REBA in forestry timber harvesting. International Journal of Industrial Ergonomics, 70, 51-57. doi:10.1016/j.ergon.2019.01.009

[3] Handbook, A. E. (1974). <Chapter-2---General-framework-and-workstation-a_1974_Applied-Ergonomics-Hand.pdf>. Volume 1, Pages 9-17.

[4] Hassim, M. H., & Edwards, D. W. (2006). Development of a Methodology for Assessing Inherent Occupational Health Hazards. Process Safety and Environmental Protection, 84(5), 378-390. doi:10.1205/psep.04412

[5] Lee, Y. S., Kang, M. R., Jung, H., Choi, S. B., Jo, K. W., & Shim, T. S. (2015). Performance of REBA MTB-XDR to detect extensively drug-resistant tuberculosis in an intermediate-burden country. J Infect Chemother, 21(5), 346-351. doi:10.1016/j.jiac.2014.12.009

[6] Li, M., Ming, X., Zheng, M., He, L., & Xu, Z. (2015). An integrated TRIZ approach for technological process and product innovation. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 231(6), 1062-1077. doi:10.1177/0954405415583885

[7] Radin Umar, R. Z., Ahmad, N., Halim, I., Lee, P. Y., & Hamid, M. (2019). Design and Development of an Ergonomic Trolley-Lifter for Sheet Metal Handling Task: A Preliminary Study. Saf Health Work, 10(3), 327-335. doi:10.1016/j.shaw.2019.06.006

[8] Serratos-Perez, J. N., Hernandez-Arellano, J. L., & Negrete-Garcia, M. C. (2015). Task Analysis and Ergonomic Evaluation in Camshaft Production Operations. Procedia Manufacturing, 3, 4244-4251. doi:10.1016/j.promfg.2015.07.407

★★★