



Renewal of "Lock-Out/ Tag-Out" Procedures in Machine Maintenance

Practical implementation

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Tämän opinnäytetyön tavoitteena on dokumentoida työsuojelustandardien uudistamisprosessi ja mahdollinen täytäntöönpano (konekohtaisten) Lock-out/Tag-out-menettelyjen osalta vaarallisen energian eristämiseksi koneiden huollon aikana.

Opinnäytetyön toimeksiantaja on UPM Specialty Papersin Tervasaaren tehtaan Valkeakosken työturvallisuus- ja kunnossapito-osasto.

Lock-out/Tag-Out eli LOTO tarkoittaa menettelyjä, joilla varmistetaan, että koneita ja mahdollisesti vaarallisia energialähteitä valvotaan, tehdään toimintakyvyttömiksi ja tarvittaessa jännitteettömiksi. Tämä mahdollistaa järjestelmän turvallisen huollon, tarkastuksen ja korjauksen.

Termiä "vaarallinen energia" käytetään kuvaamaan mitä tahansa energialähdettä, joka voi aiheuttaa vammoja huoltotoimenpiteiden aikana. Esimerkkejä näistä ovat sähköiset, mekaaniset, hydrauliset, pneumaattiset, kemialliset ja lämpöenergiälähteet. The occupational safety and health administration (OSHA) kehitti Yhdysvalloissa Lock-Out/Tag-Out-menettelyn, jonka tarkoituksena on standardoida vaarallisen energian hallinta kunnossapidon aikana.

Jotta voitiin laatia menettelytapa-asiakirja, jossa hahmotellaan kunkin konekohtaisen protokollan edellyttämät vaiheet ja tiedot, oli ensin kerättävä mahdollisimman paljon olemassa olevaa tietoa LOTO-protokollista havainnoimalla ja vertailemalla yrityksen nykyisiä turvallisuusstandardeja ja kansainvälisiä standardeja. Opinnäytetyön teoreettista vaihetta seurasi "paikan päällä" tehdastoimintojen havainnointi, ja useita huoltorutiineja tunnistettiin uudistettaviksi. Tiivis yhteistyö koneenkäyttäjien, kunnossapitotyöntekijöiden ja alueen esimiesten kanssa johti energianeristyspisteiden ja niiden valvomiseksi tarvittavien toimenpiteiden paikantamiseen ja tunnistamiseen.

Opinnäytetyöhankkeen onnistunut täytäntöönpano on lisännyt oikeiden menettelyjen näkyvyyttä, ja ne ovat kaikkien asianomaisten työntekijöiden saatavilla ja löydettävissä terveys- ja turvallisuustietokannasta. Opinnäytetyön valmistumisen aikaan ja tehdyn työn välittömänä tuloksena on ryhdytty toimenpiteisiin saman dokumentaation soveltamiseksi koneiden erityishuoltoon koko tehdasalueella.

Avainsanat LOTO, machine maintenance, hazardous energy isolation, occupational health and safety, workplace standards.

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Abstract
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The aim of this thesis is to document the process of renewal and eventual implementation of work safety standards pertaining to Machine specific Lock-out/Tag-Out procedures utilised for hazardous energy isolation during machine maintenance. The thesis has been commissioned by the occupational health and safety and maintenance departments of UPM Specialty Papers based at the Tervasaari mill in Valkeakoski.

Lock-out/Tag-Out or LOTO refers to a set of procedures designed to ensure that machinery and sources of potentially hazardous energy are controlled, rendered inoperative, and where applicable de-energized. This makes it possible to safely perform system maintenance, checks and repairs.

The term hazardous energy is used to describe any energy source that has the potential to cause injury during maintenance procedures, examples of these include electrical, mechanical, hydraulic, pneumatic, chemical, and thermal energy sources. Lock-Out/Tag-Out was developed in the United States by The Occupational Safety and Health Administration (OSHA) as a means to standardise the control of hazardous energy during maintenance.

In order to create a procedural document that outlined the steps and information required for each machine-specific protocol, it was necessary to first gather as much existing information as possible on LOTO protocols through observation and comparison of current company safety standards and international standards. The theoretical phase of the thesis was followed by physical observations of factory operations, and several maintenance routines were identified for renewal. Close collaboration with machine operators, maintenance employees and area supervisors precipitated in locating and identifying energy isolation points and steps to be taken to control them.

The successful implementation of the thesis project has led to a greater visibility of correct procedures available to all relevant employees and can be found on the occupational health and safety database. At the time of the thesis completion, and as a direct result of work undertaken steps are being made to apply the same documentation to specific machine maintenance over the entirety of the mill site.

Keywords LOTO, machine maintenance, hazardous energy isolation, occupational health and safety, workplace standards.
Pages 38 pages and appendices 1 page

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Appendix 1 Tervasaari Mill Presentation

1 Introduction

The focus of the thesis will be to review current occupational health and safety standards (OH&S) applicable to the Lock-out/ Tag-out (LOTO) procedure utilised during the maintenance, inspection, or servicing of paper factory machinery designated by the company's own work safety standards and any local legal requirements. The process is ongoing, therefore continuous review and renewal are appropriate. The thesis will make a theoretical study of LOTO procedures and document changes to OH&S standards for specific machinery, a practical approach will be taken to find solutions to improve the current procedures.

This thesis has been commissioned by the maintenance, and occupational health and safety departments of UPM Specialty Papers Oy. The documentation of the project will be carried out mainly employing Microsoft Office 365 package, work-specific software including System Analysis Program Development (SAP) and Valmet DNA Distributed Control System (DCS) user interface, will also be factored into the successful implementation of the project. Databases of current work safety standards will be used as a reference for improvement.

Initially, the working approach will be theoretical and predominantly consist of reviewing the current OH&S standards. Assisted by thorough information gathering and fact finding of current procedures, areas for improvement will be ascertained, and a plan of renewal will be developed. Proposed changes will be submitted to and discussed in collaboration with the commissioning body. The implementation of renewed OH&S standards will be planned and executed systematically once agreed upon. The final review of the project and any documentation will then be carried out. The approach to the subject will be analytical and impartial, although foresight into current working practices gained through previous on-site experience of machine maintenance and installation will be a useful addition to any theoretical findings.

First-hand observation of current procedures will be invaluable during the thesis process as well as machine operator interviews where applicable. Every effort will be made to ensure that all relevant information and observations are taken into consideration before practical changes are decided upon, thus reducing the potential for any overlooked details of significance, and further preventing possible hazardous situations. All best practices, due diligence, and work transparency will be of the utmost priority to ensure that all parties involved are satisfied with the outcome. The significance of a successful thesis project and

the utilisation of results will lead to safer working practices within the given scope of the thesis parameters. Practical benefits for the thesis commissioner will lead to a lower probability of workplace accidents, which in turn will improve productivity and more favourable working conditions. The work will be carried out on a fulltime basis at the Tervasaari site in Valkeakoski.

2 Standards; a workplace obligation

For a business to function efficiently and effectively, certain considerations must be factored into the daily operation of the workplace. As well productivity and the quality of goods or services, a company must guarantee the health and safety of its workforce. Generally speaking, individual companies might have internal rules and regulations that ensure smooth and safe procedures that must be followed by all personnel, for instance; The recording of workplace accidents, regular hazard checks, staff training, and periodic review of said regulations, can all assist in safeguarding against future potential harmful or fatal incidents.

Whilst all companies have a responsibility to best control hazardous situations internally, an obligation to follow national, and international safety standards also apply when the country the site is located is a member of the international organization for standardization. According to International Organization for Standardization (ISO) (2017), standards are defined as “requirements, guidelines, specifications, or qualities to guarantee that goods and services are trustworthy, reliable, and of high quality”.

2.1 Standards regulatory bodies and occupational health and safety (OH&S)

The phrase *occupational health and safety* (OH&S) refers to the general process of identifying and minimizing potential risks to the health and safety of workers. Risk assessment, injury prevention, work-life balance, safety procedures, workplace hazards, compensation and benefits, and employee management are just a few examples of the topics that may be covered. Since employee safety should always come first in any business, occupational safety is crucial. Employers must take care of their employees and surround them with as few risks as possible; therefore, having OH&S regulations in place can be very beneficial (Manawis, 2023).

A OH&S guide and established OH&S standards will not only guarantee a safe workplace and healthy employees, but they may also improve business. A lot of time and money can be saved by preventing and mitigating workplace hazards and injuries early on, according to studies conducted in Europe, these risks do not just affect employees physically; they also cost businesses additional money. Since motivated workers are more likely to work hard when they feel cared for and safe, a positive work environment is also associated with higher employee productivity. (Manawis, 2023)

Safety standards are devised and regulated through several regulatory bodies' dependant of locational situation, though an International Standards Organisation does exist, and any regulations set out, that apply to members of ISO, must be adhered to. A list of some of the ISO member standards governing organisations is presented below.

- ANSI American National Standards Institute
 - BSI British Standards Institution
 - CEN European Committee for Standardization
 - DIN Deutsches Institut für Normung e.V. (Germany)
 - ISO International Organization for Standardization
 - SAC Standardization Administration of China
 - SFS Finnish Standards Association
- (ISO, 2023)

The formation of the ISO began when delegates from 25 nations met in London in 1946 to discuss the future of standardization. The ISO organization was formally established a year later, on February 23, 1947. The fledgling organization's goal in 1947 was to facilitate the coordination and unification of standards created by its member bodies, each of which were national standardization bodies in their respective nations. The organization's founders decided that it would be accessible to any nation seeking to collaborate, with equal rights and obligations. These original tenets are still relevant today, and as of December 2016 ISO has grown to include 163 members from nearly every nation in the world. Since almost all facets of technology and business are now covered by ISO International Standards, standardization has come a long way and will continue to ensure improvements in a changing world. (ISO, 2023)

According to ISO (2022) "ISO 45001:2018 outlines the specifications for an occupational health and safety (OH&S) management system and provides instructions for its application to enable organizations to deliver safe and healthy workplaces by proactively enhancing their OH&S performance and preventing work-related injury and illness".

In short, it is important to follow regulated operational procedures that align with not only company standards, but also those set out by the relevant standards organisations.

2.2 Lock-Out/ Tag-Out (LOTO)

The *Lock-Out/ Tag-Out* system belongs to a series of international Standards Organisation Standards. This procedure outlines the requirements for managing hazardous energy during the servicing and/or maintenance of machinery and equipment used to avoid accidents (ISO, 2018).

The *Lock-Out/Tag-Out* procedure refers to the action of determining and ensuring the safety of a machine or process prior to and during maintenance or servicing. It was developed by Occupational Safety and Health Administration (OSHA) as a procedural practice that ensure regulations laid down by ISO (2018) "Safety of machinery - Prevention of unexpected start-up" are met, the procedure does not supersede any existing standards relating to the control of hazardous energy release.

Lock-out practices are written instructions, utilized to bring a machine to a zero-energy condition during lockout processes. To ensure that the liable employee retains control over any harmful energy, locks are attached to energy isolation devices. Tag-out tags are used to identify the employee currently working on the machine or process and acts as a visual notification that work is being carried out. (OSHA, 2002, p. 1)

The term *lockout/tagout* typically refers to lockout devices and identity tags used in combination to identify the individual responsible for the isolation of energy source. Employees can safeguard themselves against sudden re-energization or release of stored energy by adopting a lockout/tagout mechanism, and companies can benefit from increased productivity and efficiency. (OSHA, 2002, p. 1)

LOTO procedures not only protect employees from hazardous situations, but they also contribute to a company's overall efficiency and productivity by limiting the need for employee absence due to workplace injury. If hazardous energy is not adequately controlled, personnel who maintain or service machinery or other equipment run the risk of suffering severe injuries or perhaps losing their lives. Among the 3 million individuals who service equipment, craft workers, machine operators, and laborers are the most vulnerable. It is estimated that the lockout/tagout law prevents 50,000 injuries and 120 fatalities per year.

When exposed to hazardous energy at work, employees who sustain injuries lose an average of 24 days of work while they heal. (OSHA, 2002)

2.2.1 Origins of LOTO

The United States Occupational Safety and Health Administration (OSHA) created the Control of Hazardous Energy regulation in 1982 to help protect employees who frequently maintain equipment in the workplace. The regulation became fully enforceable in 1989 as statute 1910.147(c)(4)(i). The specific standards in use today have developed alongside increased workplace awareness, and a more comprehensive occupational health and safety management system (Rockwell Automation, 2022, p. 4).

2.2.2 Hazardous energy

The following hazardous energy types must be adequately controlled in facilities when servicing and/or maintaining machinery and equipment. Chemical energy such as toxic materials or contaminants, electrical energy including static, hydraulic energy such as accumulators and pressurized fluid, mechanical/kinetic energy that may include the motion of mechanical components, pneumatic energy for instance gases or compressed air in a vacuum, potential energy such as stored and gravitation energy, radiation which could refer to electromagnetic waves and radioactive energies, thermal energy including heat, cold, convection, conduction, and infrared radiation, and other energy like extreme noise. (SFS-EN ISO, 2018)

2.2.3 Five integral elements of LOTO procedure

Below is an example of a procedural list of five requirements for LOTO as designed by (Rockwell Automation, 2022, p. 6):

1. Equipment: the acquisition and supply of energy management tools. ensuring there are sufficient locks, identification tags, and isolation devices for equipment that needs to be locked out, as well as a variety of isolating devices for the various isolation points (ball valves, gate valves, breakers).
2. Training: employee training. Training should be given to both authorized and affected employees. An area's occupants during a lockout, such as operators, are referred to

as "affected", and "authorized" refers to those applying the locks. Contractors working onsite are also considered as employees in this instance.

3. Machine-Specific Procedures: creation of machine-specific energy control procedures (LOTO), At the point of use, install that procedure. These procedures' existence will not only ensure compliance but also motivate the authorized employees to adhere to them when locking out the equipment.
4. Workplace Audit: conducting a yearly (Minimum) survey of the workplace and hazard analysis to identify the machinery, apparatus, and processes that produce hazardous energy as well as the tasks that could subject workers to such energy. Keep all the information gathered during the audit as documentation of compliance.
5. Written strategy: creation of a written energy control strategy tailored to the facility. The strategy written should be particular to the location of each facility and must adapt over time. (Rockwell Automation, 2022, p. 6)

2.2.4 Machinery or equipment exempt from LOTO procedure

Under specific circumstances, a LOTO procedure is not required. OSHA has defined eight criteria that a machine must meet in order to be exempt from needing a lockout/tagout procedure. Failure to meet even one item will result in the equipment needing a documented machine-specific procedure. As set out by OSHA the following examples are exempt from the LOTO procedure:

1. No potential for leftover or stored energy is possible. Thermal sources or moving parts are two instances of residual energy.
2. The machine should only have one easily isolable energy source. Electrical, compressed gases/air, steam, water, chemicals, fuels, etc. are all examples of energy sources.
3. Isolating the machine's only energy source is required to completely deactivate it.
4. During service, the machine must be capable of being locked out.
5. Only one lockout device may be used to isolate and control the machine. It is not exempt if multiple devices are required.
6. During service, the employee must be able to have sole control of the device.
7. The worker must be able to service the machine without introducing new hazard that could endanger other workers.
8. No accidents involving the machine caused by uncontrolled energy must have occurred in the past for the company. (CRF, 2020)

2.2.5 LOTO procedure and devices


In general practice, it is required that a unique procedure is created for each specific device, however if there are multiple examples of the same machine, a procedure is written for a singular machine and can be followed for all machines/devices that meet the same specifications.

Employers are required to create, record, and implement procedures to manage potentially dangerous energy. When personnel service or maintain machinery, the procedures outline what they need to know and how to do it safely. If all the machines utilized at a workplace have the same information, then only one energy-control method may be necessary. For instance, a single technique can be used for a group of similar machines that use the same kind and quantity of energy and the same or similar sorts of control measures. If a workplace has more changeable conditions, such as diverse energy sources, various power connections, or various control sequences that employees must follow to shut down various pieces of machinery, the employer must create separate energy-control methods. (OSHA, 2002, p. 7)

The scope, purpose, authorization, regulations, and methods that workers will use to manage hazardous energy sources, as well as the tactics that will be utilized to ensure compliance, must be laid out in the energy-control processes. Employees must receive at a minimum the following information from these procedures (OSHA, 2002, p. 7):

- I. A description of how to apply the methods.
- II. Steps to specifically turn off, isolate, block, and secure machines.
- III. Specific guidelines for testing machines to ascertain and confirm the efficacy of lockout devices, tagout devices, and other energy-control measures.
- IV. Specific steps designating the safe placement, removal, and transfer of LOTO devices and identifying who has responsibility for the LOTO devices. (OSHA, 2002, p. 7) figure 1 shows an example of a LOTO procedure card.

Figure 1 Lockout/tagout procedure (Rockwell Automation, 2022, p. 14)



LOCKOUT/TAGOUT PROCEDURE
OSHA CFR 1910.147

Developed by	Reviewed by	Revised by
RA	RA	

Description: Chiller
Equipment #: CH2

Area: Utilities
Location: Chiller Room
Rev: 0
Date: N/A
Origin Date: 1/2/2019

5


Isolation Points to be Locked and Tagged

CAUTION


Pressurized refrigeration loop to be serviced by authorized personnel only.

The audit record of this procedure is tracked electronically. Scan the barcode or locate the procedure to audit.


North Side View



West Side View



South Side View



REFERENCE MACHINE SHUTDOWN STEPS BEFORE LOCKING OUT

ID	Source	Device	Location	Method	Check
← E-1	Electrical 480V	Padlock	Isolation point on North side of unit.	Move electrical disconnect to off. Lock out.	Attempt restart at CP-1.
← W-1	Chilled Water Inlet - 80 PSI	Cable device	Isolation point on West side of unit.	Turn valve to closed position. Lock out.	Visually verify zero pressure status.
← W-2	Chilled Water Outlet - 80 PSI	Cable device	Isolation point on West side of unit.	Turn valve to closed position. Lock out.	Visually verify zero pressure status.
← W-3	Condenser Water Inlet - 80 PSI	Cable device	Isolation point on South side of unit.	Turn valve to closed position. Lock out.	Visually verify zero pressure status.
← W-4	Condenser Water Outlet - 80 PSI	Cable device	Isolation point located above unit.	Turn valve to closed position. Lock out.	Visually verify zero pressure status.
	Thermal Energy 200 F		Be sure to wait until unit reaches a safe temperature before servicing. Wear proper PPE before beginning work.		
	Kinetic Energy 1800 RPM		Be sure to wait until all moving parts have come to a complete stop. If necessary, use a block or chain to prevent equipment from moving while servicing.		

DANGER

rok.auto/LOTO

Any machine modifications must be shown in procedure. Contact safety department to update procedure.

Safety Is Your Responsibility!

DANGER

Rockwell Automation

Page 1 of 1
SAMPLE - Utilities - Chiller Room - Chiller - CH2.xlsx

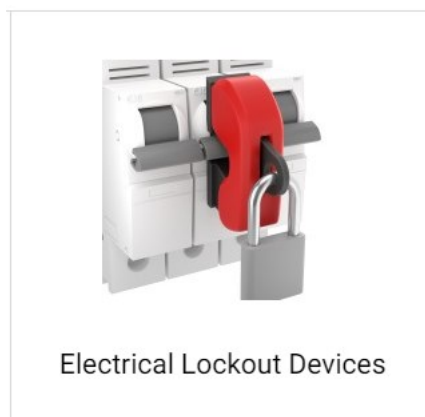
In order to keep equipment from being removed and from being reenergized while being repaired, LOTO padlocks are attached to lockout devices and hasps. It is impossible for another technician to unintentionally remove the lock since each professional has a key that is exclusive to their lock or set of locks. When equipment is being maintained, electrical lockout mechanisms stop power from being restored or from being energized. They are a crucial component of LOTO method for facilities that complies with the OSHA standard for the control of hazardous energy. To stop equipment from being re-energized, power is turned off and the lockout device is engaged. It is necessary to use a LOTO padlock to stop

unauthorized workers from removing the lockout. Figures 2-3 are respectively example representations of an LOTO padlock and an electrical lockout device. (Grainger, 2023)

Figure 2 LOTO Padlock (Grainger, 2023)



Figure 3 Electrical lockout. (Grainger, 2023)



While working on downstream pipe and equipment, valve lockout devices prohibit energy isolation valves from being opened. Before the lockout is implemented, the valve is closed to de-energize the pipe. The lockout is secured with a padlock to prevent unauthorized employees from removing it. Different types of valves and valve handles require different

valve lockout procedures. All valve types are secured by universal lockouts. To prevent flange opening while the pipeline is undergoing maintenance or repair, and potentially releasing steam or pressurized fluid, flange lockout devices cover bolts on pipeline flanges. The lockout must be secured with a padlock to prevent removal by unauthorized personnel, and where applicable identity tags should be visible. Figures 4-5 show basic examples of a valve lockout and a pipe flange lockout device. (Grainger, 2023)

Figure 4 Valve Lockout (Grainger, 2023)



Valve Lockout Devices

Figure 5 Flange Lockout (Grainger, 2023)



Flange Lockout Devices

To notify workers that the equipment is locked out for service, tagout tags slide over the shackle of a padlock. These tags are a crucial component of LOTO method used in facilities to comply with OSHA's standard for the management of hazardous energy. When equipment is being serviced, lockout keys are placed in group lockout boxes, where they are kept safe.

Since each worker only needs to apply one lock in one location rather than at every lockout point, they reduce the number of locks required for large operations. At the control point, each lockout is secured with a single lock, and the key for that lock is stored in the lockout box. Then, each worker secures the box with a personal lockout padlock and removes their own key. As they work on the machinery, the workers add and remove their locks. The keys to open the padlocks on the equipment are available to the last person to finish their task and remove their lock. Figures 6-7 are examples of tagout tags and a group lockout box. (Grainger, 2023)

Figure 6 Tagout Tag (Grainger, 2023)

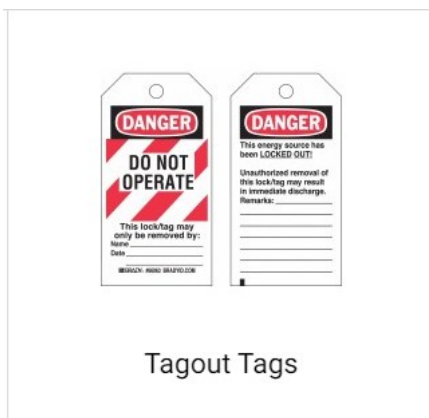
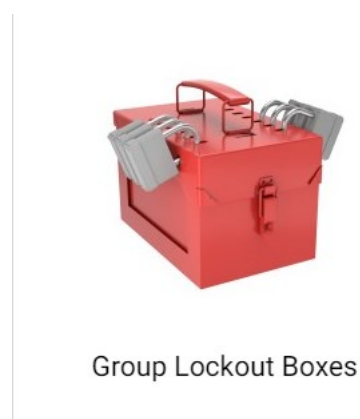


Figure 7 Group Lockout Box. (Grainger, 2023)



2.2.6 Commonly used phrases relating to LOTO

Table 1 lists some key phrases relating to LOTO procedure as described by the Occupational Safety and Health Administration:

Table 1 Common phrases relating to LOTO. (OSHA, 2002, p.21)

Affected employee.	An employee whose job involves operating or using machinery or equipment that is undergoing lockout or tagout maintenance, or whose job requires them to work in an area where such servicing or maintenance is being performed.
Authorized employee.	A person who locks out or tags machinery in order to service or maintain that machinery or equipment. Affected employees are then regarded as authorized employees if they carry out servicing or maintenance covered by the standard as part of their regular duties.
Energy-isolating device.	A mechanical device that physically prevents the transmission or release of energy, including but not limited to an electrical circuit breaker that must be manually operated; a disconnect switch; a switch that must be manually operated so that no pole can be operated independently; a line valve; a block; and any other similar energy-blocking or isolation device. Devices of the control circuit type, such as pushbuttons, selector switches, and others, are not energy-isolating devices.
Energy source.	Any source of energy, be it thermal, chemical, electrical, mechanical, hydraulic, or pneumatic.

Lockout.	Placement of a lockout device on an energy-isolating device in accordance with a set procedure to prevent operation of the energy-isolating device and the controlled equipment until the lockout device is removed.
Tagout.	The practice of attaching a tagout device to an energy-isolating device to indicate that operation of the energy-isolating device and the controlled equipment is prohibited until the tagout device has been removed.
Maintenance and/or Servicing.	Performing tasks related to building, installing, setting up, adjusting, inspecting, modifying, maintaining, and/or servicing machines or equipment. These tasks include lubricating, cleaning, or unjamming machines or equipment, as well as adjusting or changing tools, where the employee may be exposed to the equipment's unplanned startup or energization or to the release of hazardous energy.

3 Tervasaari; operations and machinery

UPM Specialty Papers Tervasaari, based in Valkeakoski has been producing paper for over 150 years, main operational machines and processes today consist of:

- PM 5 (paper machine 5)
 - Machine startup date: 1938.
 - Paper roll width: 4.3 metres.
 - Products: Glassine, release base paper for self-adhesive laminates and tape end uses.
 - 1 multiroll calender, 1 winder.

- PM 8 (paper machine 8)

- Machine startup date: 1996.
 - Paper roll width: 6.4 metres.
 - Products: Glassine and SCK's (Super calendared Kraft), release base paper for self-adhesive laminates and tape end uses.
 - 2 supercalenders, 1 winder.
- Power Plant
 - Generates electricity and process steam for the paper mills.
 - The mill's power plant generates approximately a third of the required electricity.
 - The power plant generates all heat required by the Tervasaari mill.
 - District heating and steam are additional forms of heat sold to outside customers. The mill generates Valkeakoski's district heating.
 - 55% of fuel utilised is biomass-based.
 - Share of non-fossil CO₂ fuels are >65%.
 - The electricity used is 93% fossil CO₂ free and 71% total CO₂ free.
 - Two boilers—one using natural gas and the other solid fuel—produce the majority of the heat energy.
- Water treatment, effluent treatment
 - The production of pulp for paper and the cooling of machinery and other equipment both require water.
 - Mallasvesi Lake serves as a source of water.
 - The water station purifies lake water.
 - Wastewater from production is treated.
 - Primary treatment clears wastewater of solids.
 - Biological treatment purification occurs When microbes are added to wastewater after primary treatment.
 - Excess bio sludge is compressed and dried before being burned at the power plant. (Appendix 1. UPM, N.D.)

3.1 Potential hazards on site

During production operations it is essential to always maintain safe procedure, appropriate safety clothing should be worn at all times as well as a safety helmet, protective eyewear, ear protection, and safety shoes. Any incidents considered a breach of procedure or pertaining to

an accident on site is documented and regular safety reviews are carried out to safeguard against incidents of the same nature occurring, table 2 lists some examples of the types of machinery and equipment on site and potential hazards they may cause.

Table 2 List of potentially hazardous machinery

Motors:	A variety of motors are used on site, potential hazards could include body parts trapped in moving parts, electric shock due to loose wiring or unexpected startup, high noise level that can cause hearing damage.
Paper machine rollers:	Trapped body parts, danger from roller falling during lifting operations, some rollers are heated or contain pressurised fluid and can be hazardous if unexpected pressure release occurs, high noise level that can cause hearing damage.
Pumps:	Examples of pump hazards could include body parts trapped in moving components due to unexpected startup, loose particles can fly off pump when in operation which may cause injury, high noise level that can cause hearing damage.
Cranes:	Overhead cranes utilised in the production areas pose a significant threat if correct work protocol is not followed, hazards could include injury from falling equipment or products or impact from swinging hooks. Helmets must be worn at all times in production areas.

Forklift trucks:	Hazards relating to forklift trucks include impact from truck in motion, or injury from falling objects being lifted.
Pressurised Pipes and/or Vessels:	Throughout the work area numerous pressurised pipes and tanks can be found as a result of production processes, these may contain gasses or fluid under high pressure or temperature, there is a risk of injury to eyes or exposed skin if leakage occurs.
Chemical tanks:	Chemical spillage or sudden depressurisation of tanks may be hazardous due to potentially harmful substances.
Compressors:	Compressor-related risks include sudden pressure releases that can seriously harm soft tissue, electrical risks like electrical shocks or irreversible machine damage, toxic fumes from gas- and diesel-powered compressors, excessive noise levels that can harm ears, and flying objects and debris that can injure people.
Hydraulic components:	Hazards of hydraulic components can include a risk of explosions and flames when a hydraulic line breaks and releases combustible liquid, person could be struck by a pressurized hose that whips around, the loss of fluid pressure from a broken or failed line might force machine components to collapse, potentially injuring or killing a worker beneath the machine, a hydraulic line with a pinhole leak may allow pressurized fluid to be injected

	under the skin. This wound may become infected.
--	---

3.2 Machine maintenance

For many industries, maintenance expenses make up a sizeable portion of total operating costs. Occasionally, maintenance expenses account for about 50% of the costs associated with manufacturing. Unexpected occurrences like premature equipment failure can result in unforeseen costs that are challenging to control. Productivity subsequently depends not just on the human factor but is also strongly influenced by the accurate production flow of all machines involved in any given process. In an industrial context, the role of routine machine maintenance is crucial to the efficient operation of any organization. (Quality Millwright, 2019)

Machines are susceptible to disrupting operations through failures, malfunctions, etc., in the same way that human error may. Effective mitigation of production disruption requires efficient maintenance techniques and practices. It is crucial to consider the different forms of machine maintenance, their applications, optimal timing, and cost-effectiveness. According to Picomto (2022), The five main forms of maintenance utilised in an industrial setting are as follows:

1. Corrective maintenance:

As the name suggests, corrective maintenance is performed to address equipment deterioration and faults as soon as they happen. Industrial maintenance specialists take care of the issue as soon as it arises if the breakdown that disturbs the manufacturing process has not been foreseen by other types of maintenance, such as preventative maintenance. This is unscheduled preventive maintenance, often known as curative maintenance. Companies may incur costs as a result of this form of action. Manufacturers employ the so called "palliative corrective maintenance" to reduce the cost of repairs, which entails correcting the issue more swiftly and cheaply.

2. Preventive maintenance:

The industrial maintenance technicians carry out this kind of maintenance in advance of any failure or malfunction. In order to lower the risk of failure, it concerns spare parts, components, machinery and equipment. Numerous computerized and technological solutions have been made available as a result of the industrial sector's

digitalization, enabling technicians to effectively perform, monitor, keep track of, and plan preventive maintenance.

3. Predictive maintenance:

Manufacturers can now plan predictive maintenance based on forecasting of failures and malfunctions, due to the advancement of data processing, analysis tools, and artificial intelligence. By organizing the required interventions and maintenance operations based on predictions, this kind of industrial maintenance enables companies to foresee issues. As a result, it allows for the reduction of costs brought on by unforeseen failures, equipment downtime, and production interruption.

4. Systematic preventive maintenance:

This type of preventive maintenance is distinguished by its frequency. The technicians carry it out regularly and methodically at predetermined intervals of time. As a result, machine productivity is increased through the routine replacement of parts and spares. Thus, systematic preventive maintenance is based on routine inspection of the various pieces of equipment, allowing maintenance specialists to gather the necessary data on the various parts of the production line and to successfully prevent breakdowns and repair costs.

5. Conditional preventive maintenance:

Monitoring the important operational parameters and indicators and taking the appropriate corrective action in advance of any failure or malfunction constitute conditional preventive maintenance. This kind of industrial maintenance can be automated with a variety of emerging computer tools. By choosing to digitalize industrial maintenance processes, technicians and maintenance workers can simplify and facilitate their work. (Picomto, 2022)

3.3 Site specific maintenance

The mill site operates full-time seven days a week, and on-site maintenance is divided into sections according to procedural or functional distinctions. Typically, a three-shift schedule is used for work rotation. A second dayshift on weekdays is established for specialized duties in addition to the shift maintenance crew. Generally, teams dedicated to mechanical, automation, and energy (powerplant) maintenance are divided. The following tasks are

assigned under the separation of functions: maintenance planning, paper machine maintenance, preventative maintenance, general maintenance, and development maintenance.

Maintenance planning and documentation are carried out employing SAP software platforms, an extensive database of records relating to costing and efficiency is further utilised for future predictive and preventative maintenance purposes. When it was first established in 1972, the business was known as System Analysis Program Development, which ultimately changed to SAP. SAP created the Enterprise Resource Planning (ERP) software an industry standard worldwide. The company's integrated apps replace the process-driven, legacy platform by bringing all aspects of a business together into an intelligent suite on a fully digital platform. Currently, SAP has the largest cloud portfolio of any supplier, over 230 million cloud users, and over 100 solutions encompassing all business processes. (SAP, N.D)

Process control automation and information is provided by Valmet DNA. It integrates into a single platform all controls related to process, machine, quality, supervisory, drive, optimizations, and mechanical condition monitoring. Batch solutions and Safety Instrumented Systems are also included in a Valmet DNA scope. Additionally, Valmet DNA can be utilized as a SCADA, Soft PLC, or PLC. Valmet DNA can support global organizations with micro-size systems, such as the smallest fully functional user interface in the world, or with mill- and plant-wide systems. (Inteka, 2022)

The current status of processes can be observed remotely through the utilisation of Valmet DNA distributed control systems, the below figures 8-9 are some generic examples of SAP and Valmet DNA.

Figure 8 SAP Workload Analysis (ST03N) – Time Profile (Wong, 2020).

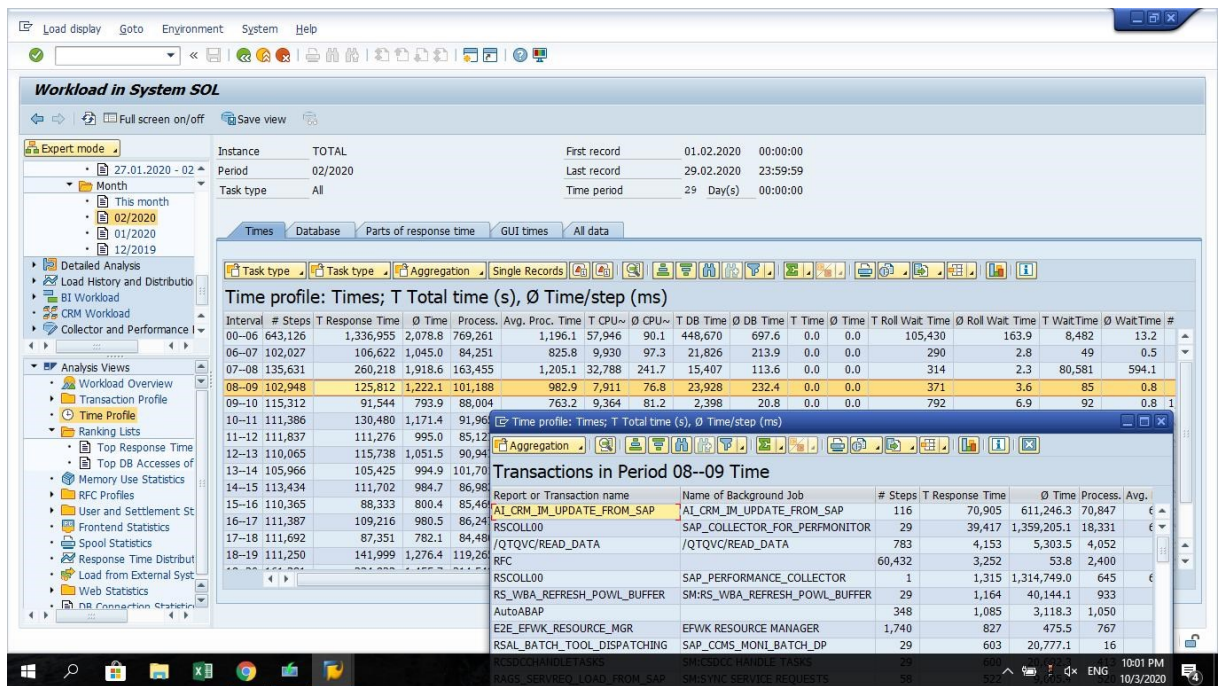
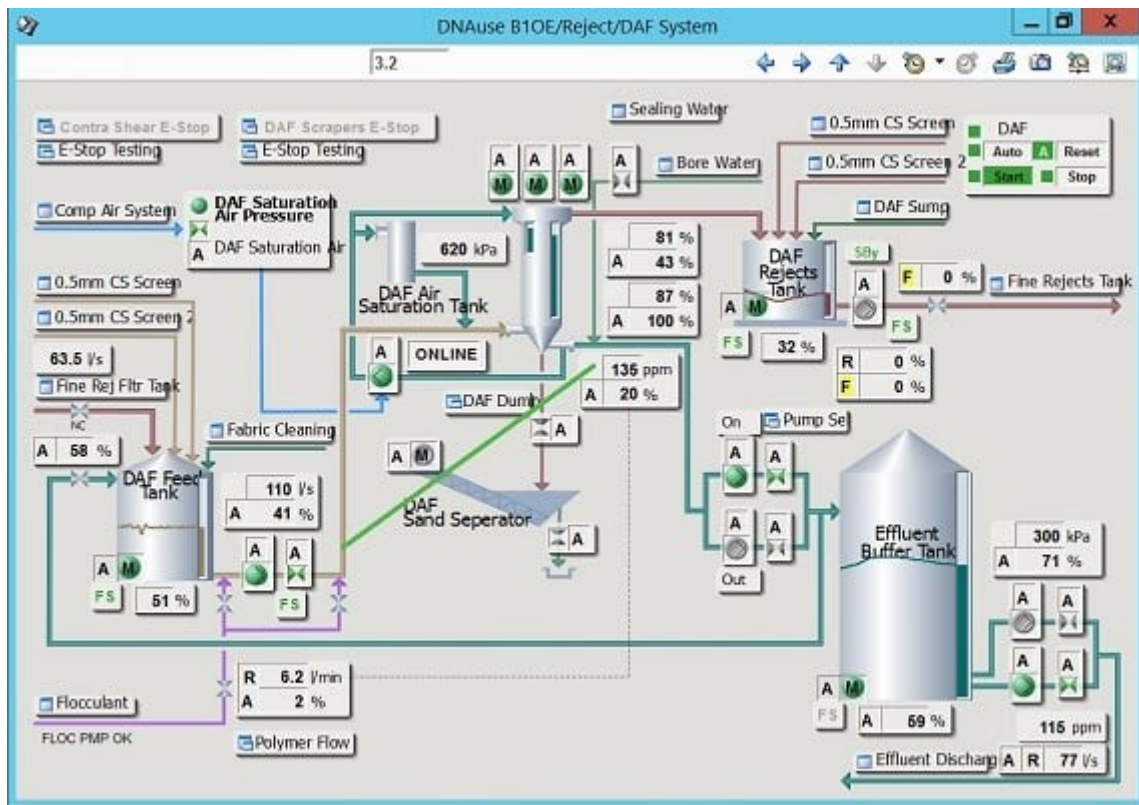


Figure 9 Reducing flocculent usage leads to cost savings in wastewater treatment (Valmet, 2020).



3.4 Current OH&S standards relating to LOTO procedure

Outline of current procedures in place align with international standards. According to OSHA (2002), Each distinct machine or machine station for integrated equipment, should be designated a unique specialised LOTO method. These procedures should only be created by qualified employees, for instance a person who is familiar with the various energy sources, energy isolation devices, and their placements. All procedures should be readily accessible, posted at equipment, or otherwise made available to the corresponding maintenance team, machine operator, or shift supervisor. When applicable, machine specific LOTO protocols must include the following:

- I. The machine, equipment, or process identification.
- II. All hazardous energies and magnitudes thereof are listed.

- III. A list of all energy-isolating devices, together with their locations and identification numbers (IDs)
- IV. Steps for shutting down, isolating, blocking, securing, and relieving stored or residual energy.
- V. procedures for installing lock-out devices.
- VI. Employees can use various techniques (such as attempting to start the machine), to confirm that isolation and de-energization have been completed.
- VII. Removal procedures for lock-out devices.
- VIII. Taking action to return equipment to regular operation (including notifying others);
and
- IX. Dates for both the intended review and the creation of the procedure.
(OSHA, 2002)

4 Practical implementation

Practical implementation of the project will run concurrently with a companywide pilot project designed to allow for on the job training materials to be available to operators and maintenance workers in real time through the use of an smart device application, and the successful realization of said pilot project is dependent on the effective outcome of a renewal of machine specific LOTO procedure, it is worth verifying that for the purposes of this report only a single procedure has been documented thoroughly, a short list of procedures to be renewed within the boundary of the project are listed for reference purposes. The implementation report will focus on renewal of a machine procedure for paper machine 5, a detailed list of machine procedures will be further explored in chapter, 4.1.

The initial stage of implementation is a thorough review of processes and data pertaining to LOTO procedures currently in practice at UPM Specialty Papers. Following the review, observation, and documentation of procedures in a practical setting will take place along with machine operators, maintenance workers, shift managers, and heads of department. Based on the findings, specific machine procedures will be identified for updates. In collaboration with the occupational health and safety team, new LOTO procedures will be devised and

submitted for approval. If approved the new procedures will be drawn up and added to circulation included in renewed LOTO standards, this is an ongoing process and will be reviewed annually.

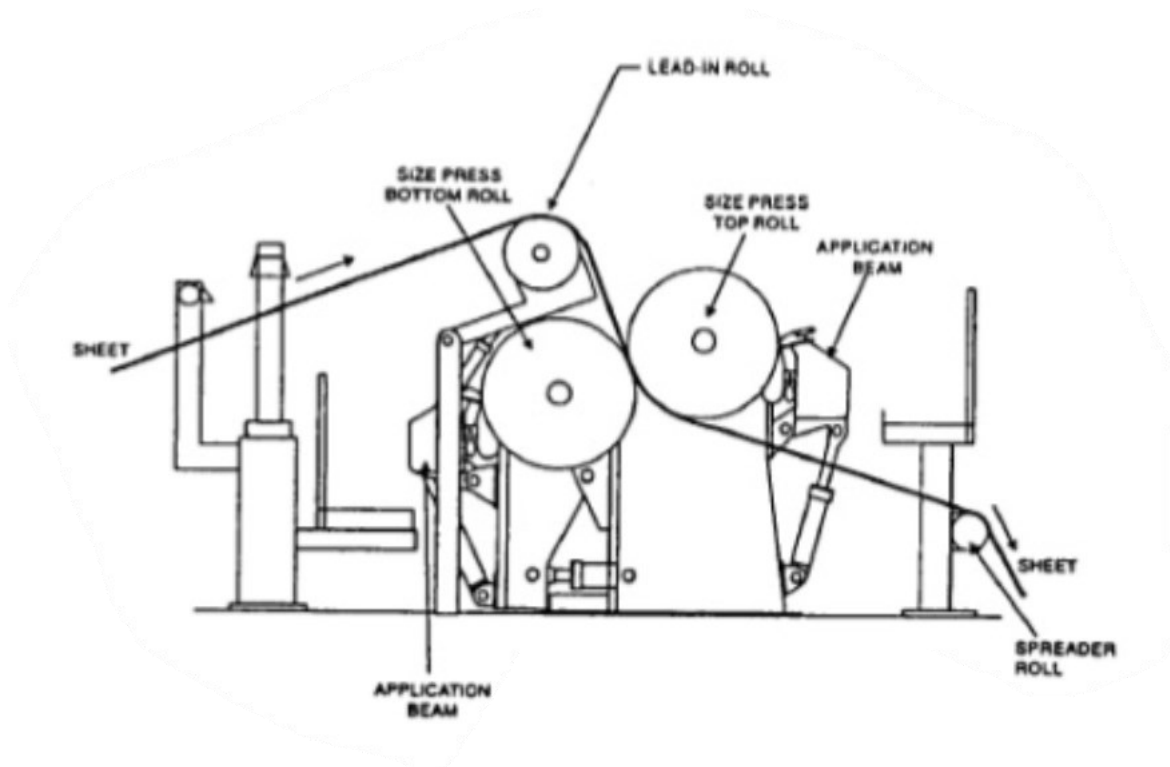
4.1 Specific machine procedures to be renewed

Identification of specific machine LOTO procedures for paper machine 5 to be renewed was an essential step in implementation, from the stated procedures a process that indicates a good representation of aforementioned LOTO energy isolation will be selected and documented in full. Below can be viewed the initial procedures to be renewed and a description of the machine functions.

I. Sym Sizer press roller replacement

The size press comprises two-roll presses with either pneumatic or hydraulic loading, the paper surface is treated as it passes between the rollers with an adhesive coating utilising spray jets and the roller pressure to distribute evenly. Figure 10 shows a representation of the sym-sizer press. (Papcel, 2023)

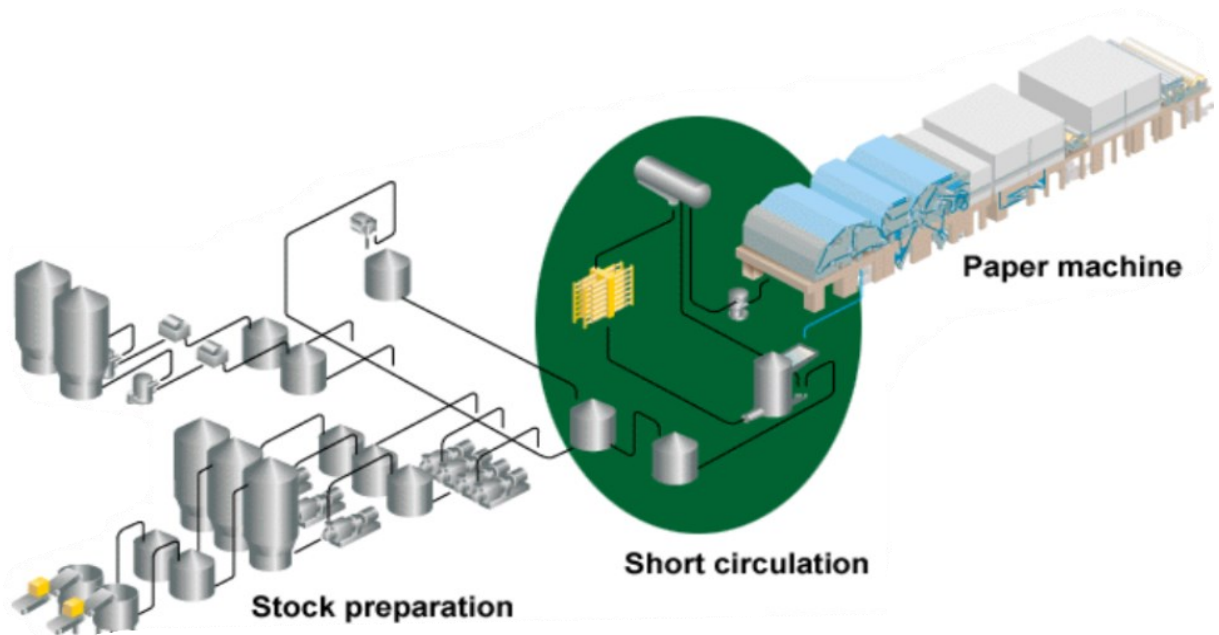
Figure 10 Sym Sizer. (Nugroho, p.9, 2019)



II. Short circulation maintenance

Utilizing collected and repurposed white water in the production of paper and board minimizes the need of fresh water, energy consumption, and loads and losses in sewers. White water extracted from the stock on the former is swiftly returned to the thin stock system and headbox via the primary white water circulation loop, also known as the short circulation loop. Figure 11 shows the short circulation process. (Tappi, 2023)

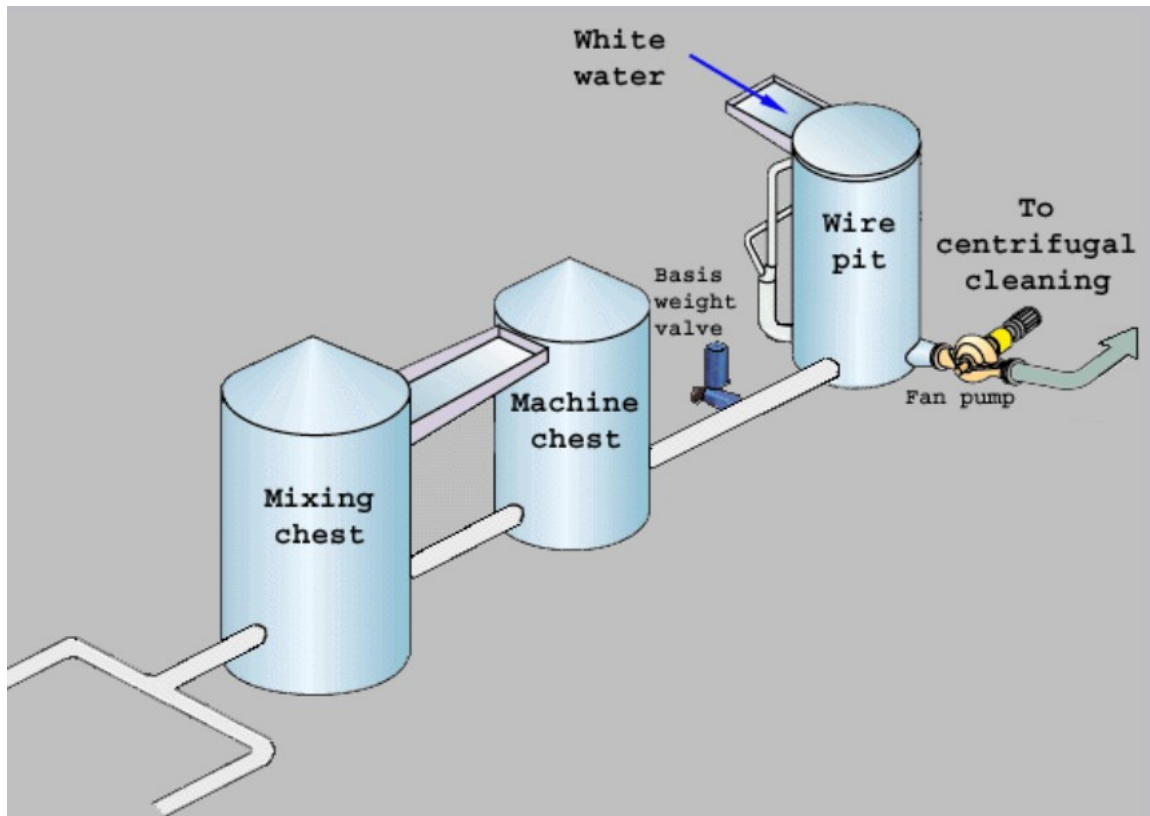
Figure 11 Location of short circulation. (Metso Paper, 2012)



III. Maintenance of machine chest

The paper machine's mixing chest is a sizable, agitated tank that is used to combine different kinds of pulp, additives, and fillers according to a predetermined recipe. The blended material is supplied to the machine chest, where it is pushed to the headbox and uniformly distributed onto the papermaking machine's moving wire. Figure 12 shows the Machine chest and wire pit sections of the forming process. (Alutal, 2023)

Figure 12 Machine chest- wire pit. (KnowPap, 2023)



IV. Conical refiner maintenance procedure

In the paper-making process, the refining phase describes the fibre breakdown activity. How many bonds can be formed depends significantly on the degree of fibre breakdown and the resulting increase in the contact area between the fibres. (World Paper Mill, 2019)

In the case of conical refiners, pulp enters via a feed port. It then exits via the discharge/release port after passing through the conical rotor and stator. Bar and groove patterns are combined in the stator and rotor. While the stator stays stationary, the rotor revolves. Accelerating the rotor and stator simultaneously regulates the space between the refiners. Figure 13 shows an example of a Valmet conical refiner. (World Paper Mill, 2019)

Figure 13 Conical Refiner Conflo. (Valmet, 2019)



V. Filtomat process filter maintenance

Process water is utilized in production procedures and has a direct impact on the quality of the final product. Reducing scrap and downtime and achieving efficient production depend on a steady and uninterrupted water supply. Appropriate filtration equipment is necessary to control the necessary process water quality and provide optimal processes. Figure 14 shows an example of a Filtomat process water filter. (Amiad Water systems, 2023)

Figure 14 Filtomat M104XLP/M106XLP/M108LP/M110P. (Amiad Water Systems, 2013, p. 6)



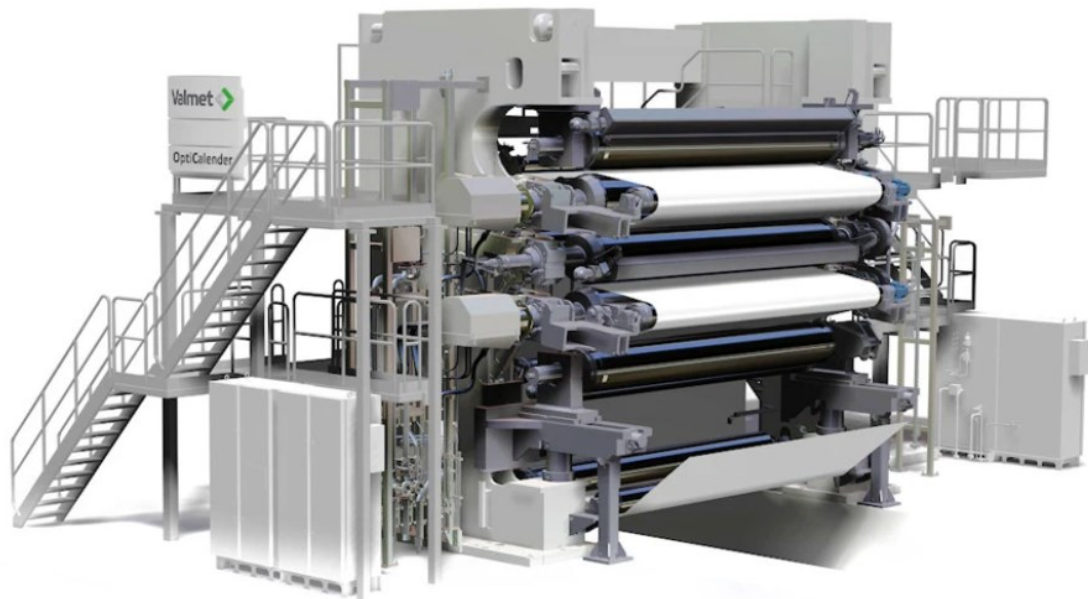
VI. Maintenance of “Wire pit” forming section

The wire is a component of the paper machine used in the production of paper that forms the paper sheet. It also goes by the name of the paper machine's forming section. The wire segment significantly affects how the sheet forms. The drainage elements' pressure pulses during the sheet-forming process guarantee that any forming fibre flocs are broken up and that the sheet forms uniformly and well. The paper sheet, also called the paper web, is created by the wire passing over suction boxes that remove water through suction. The chest where the white water collected after the stock is dewatered on the wire is called the wire pit. There needs to be a steady level in the wire pit. Since some of the white water always overflows, a consistent level is achieved. (DS Smith, 2023)

VII. Replacement of calender steam rollers

In the paper manufacturing process, a paper calender steam roller is used to enhance the surface quality of paper and board through pressure and heat. Figure 15 shows a representation of a multi roll calendaring machine process. (Valmet, 2023)

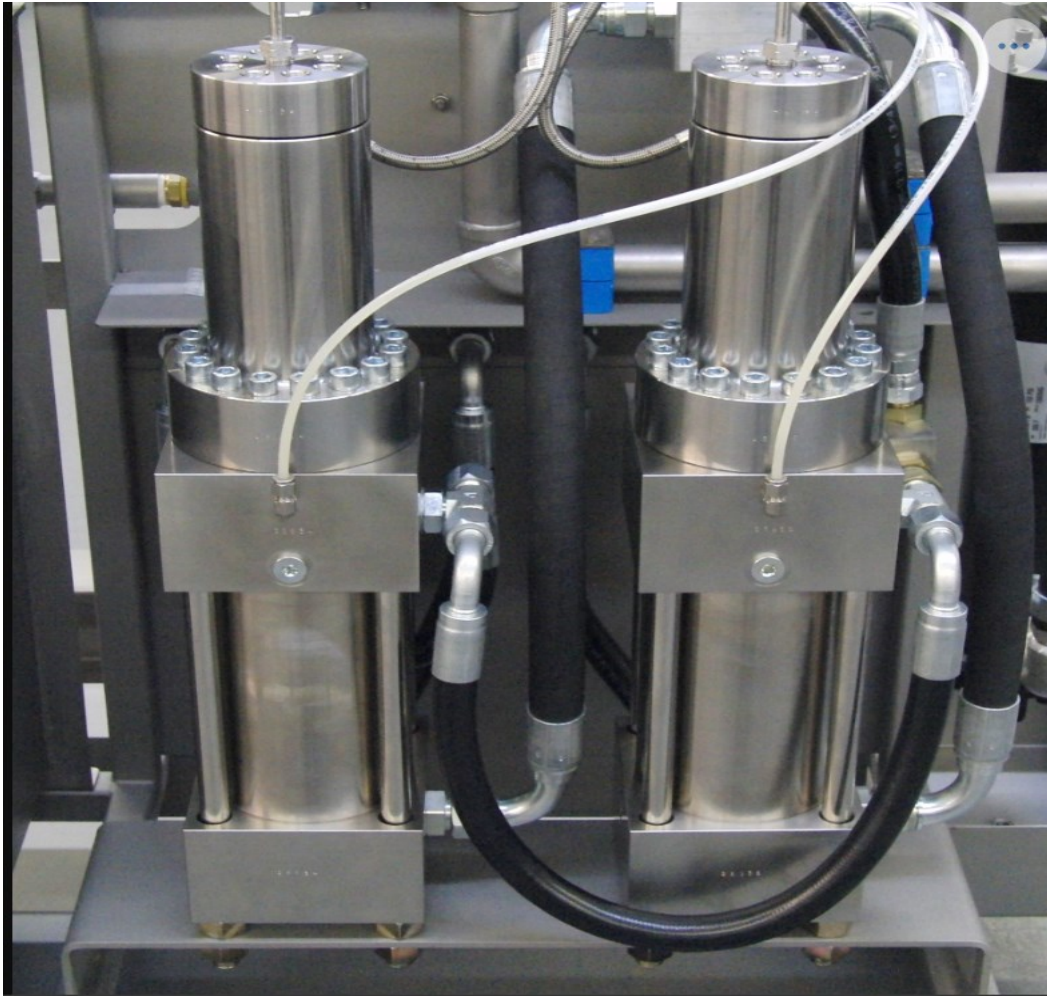
Figure 15 OptiCalender Multinip. (Valmet, 2023)



VIII. Paprima pressurised water jet maintenance

A pressurised water system for trimming paper web whilst roller is in motion. An external water jet is used by the water-jet edge trimmer to cut the sheet. The sheet receives no mechanical stresses. There are numerous benefits to this: When beginning to trim, the jet does not damage the sheet, additionally it is Insensitive to caliper, tension, moisture, speed, or sheet oscillation this results in a narrower trim removal and positively effects the trim higher range. In order for the water jet to run efficiently it must maintain high pressure, this procedure focuses on the maintenance of the high-pressure system. Figure 16 shows a Paprima high-pressure system. (Paprima, 2016)

Figure 16 Paprima High-Pressure System. (Paprima, 2016)

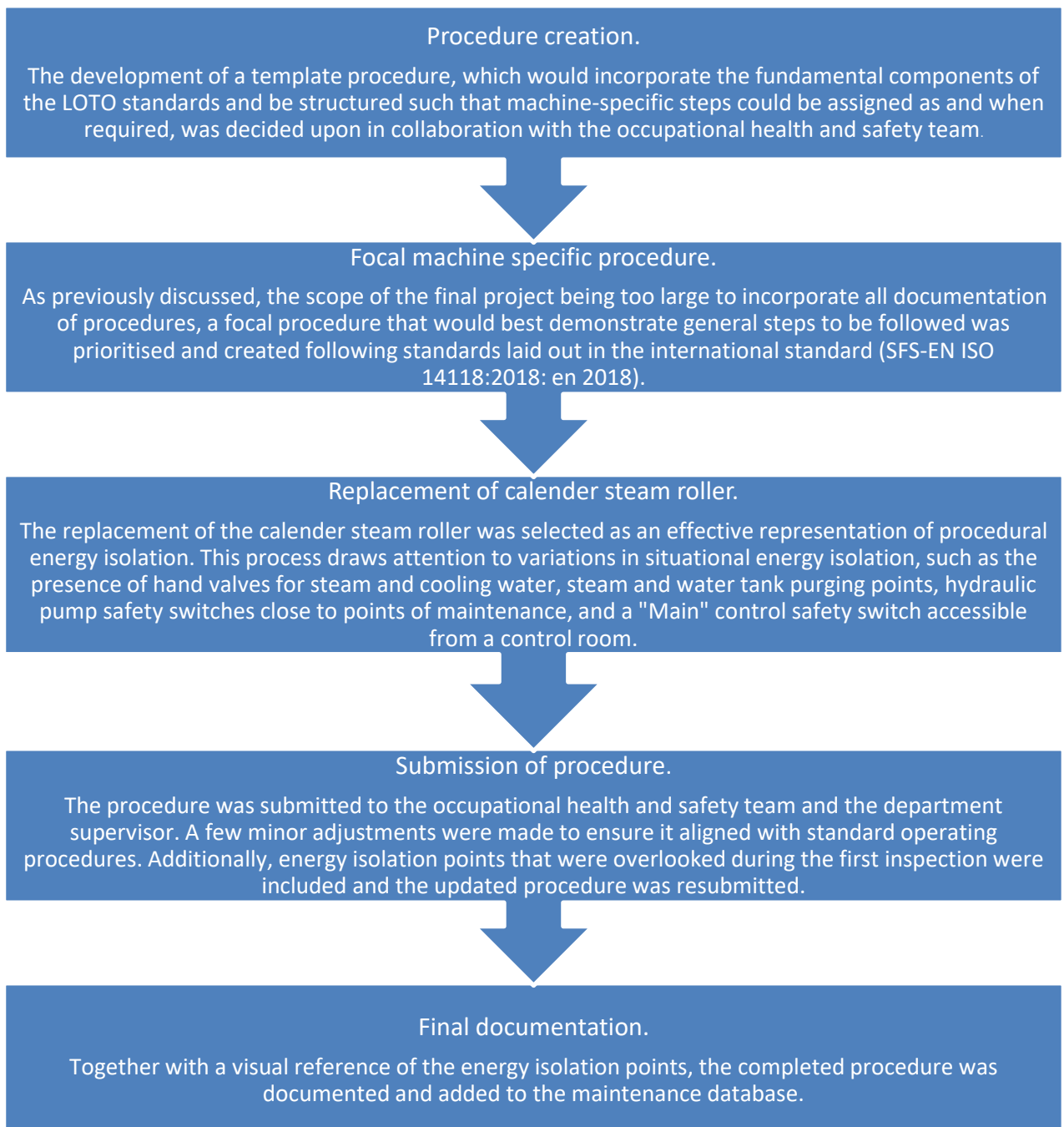


5 Summary of work

In order to clearly summarise the project as a whole, a flow chart has been used to represent the process stages, each block of the flow chart denotes the core elements of the work carried out in chronological order. Realistically the project is still underway, for the purposes of coherent documentation, only work pertaining to the thesis project in its entirety has been included in the summary. All steps were carefully processed and reviewed for relevance to the final thesis. The outline of the project steps are documented in figure 17.

Figure 17 Summary of work.





5.1 Updated LOTO procedure

The finalisation of the updated procedure has been accepted by the commissioning body and will be in circulation until such time that a procedure review is deemed appropriate, this practice generally takes place annually barring any unforeseen issues and is common practice in the production and process industries. Figure 18 shows the procedure submitted to management.

Figure 18 Updated LOTO procedure

SAFETY ISOLATION						
Position / Target:		SC51 Steam rollers				
Works on the site:		Replacing the calender _____ steam roller(s)				
Energy type:		<ul style="list-style-type: none"> • Thermal energy (hot surfaces, steam rollers and lines) • Potential energy • Pneumatic energy (automatic valves) • Electricity (motors) • Mechanical/kinetic energy (rotating rollers and motors) • Hydraulic energy (hydraulic pumps) 				
Date:						
Separable devices						
Devicetype:	Destination:	Position:	Sign/lock number	Separation made nIMI	Test start done nIMI	Returned nimimark
Manual valve	Main steam valve closed (20 Bar)					
Safety switch	Drive voltage off and safety switch on					
Manual valve	Condensate tank for drainage open					
Manual valve	Joint emptying of steam roller steam line open					
Manual valve	Hand valve of steam entering the roller closed					
Manual valve	Hand control of condensate leaving the roll					
Manual valve	Both water valves go to the steam box					
Safety switch	Circulating pump for bearings HP Calander safety switch on	75E224-1				
Safety switch	Bearing circulating aid pump. HP Calander safety switch on	75E225-1				
Safety switch	Circulating pump for bearings KP Calander safety switch on	75E226-1				
Safety switch	Bearing circulating aid pump. KP Kalanteri	75E227-1				

	safety switch on					
Safety switch	CALANDER HYDRAULICS Main pump safety switch on	750K345				
Safety switch	CALANDER HYDRAULICS Spare pump safety switch on	750K345				
Safety switch	CALANDER HYDRAULIC KA Cooler/Filtration pump safety switch on	750K345				
Steps						
1.	Notification to all employees affected by the work.					
	<ol style="list-style-type: none"> 1. Have the affected employees who operate or work near the equipment been informed of the difference? Yes/No 2. Is the operator aware of the additional safety requirements for the equipment? Yes/No 					
2.	Energy sources					
	<ol style="list-style-type: none"> 1. All energy sources are correctly identified and documented on the form? Yes/No 					
3.	<ul style="list-style-type: none"> • Normal stopping and cooling of the calender. • Calender for roll change mode from the Siemens control display. • Control voltage of the calender drives to position 0 and safety switch on and attachment of the lock to the safety switch. • Drive safety switch on the control panel on the control room table. 					
4.	<ul style="list-style-type: none"> • Turn the main steam hand valve shut from the calender pit treatment platform. Attach the security lock and/or separation sign. • Call the energy control room at 0204162676 and catch the main vapours of the calender at the end of the energy. (Valve in the old turbine hall, remains on the left side of the stairs ascending from the room to the maintenance platform. The stairs on the right side of the level lead to the old auxiliary condenser and the VPT2 hall) 					
5.	<ul style="list-style-type: none"> • Open the drain valve of the condensate tank and mark with a separation sign. • The joint emptying of the roller steam line is open from the bottom of the deck and marked with a separation sign. • The steam manual valve of the replaceable steam roller is closed and marked with a separation sign. • The hand valve of the condensate of the roller to be replaced is closed and marked with a separation sign. • Hand valves for rollers on the care side of the deck approximately at the level of the replaceable steam roller. • Both water valves go to the steam roller box 					
6.	<ul style="list-style-type: none"> • The rotation lubrication is stopped and locked by the safety switches: 					

	<ul style="list-style-type: none"> • Bearing vending pump HP Calander (75E224-1), Bearing auxiliary lubrication pump HP Calander (75E225-1), Bearing vexation pump KP Calander (75E226-1), Bearing auxiliary lubrication pump KP Calander (75E227-1). • Turn the safety switches on all pumps and attach safety locks and marks to all switches. Safety switches can be found on both sides of the deck in the calander pit in connection with the lubrication units.
7.	<ul style="list-style-type: none"> • The hydraulic pumps are stopped and locked by means of safety switches: • CALANDER HYDRAULICS (750K345) 1. Main pump 2. Spare pump 3. Cooling/filtration pump. • Turn the safety switches on all pumps and attach safety locks and marks to all switches. The safety switches can be found in the calander pit at the stern in the hydraulic compartment behind the deck.
8.	<ul style="list-style-type: none"> • Check energy isolation • The operator must ensure the difference in energies before starting work at the time of test start-up of the machinery. A test start ensures that the safety switches are intact and working properly. Ensuring the separation of the steam and condensate sides, whether the surfaces are hot, whether flow is visible in the sight glasses of the steam and condensate lines.
9.	<ul style="list-style-type: none"> • Carrying out maintenance and repair work
10.	<ul style="list-style-type: none"> • Return devices to normal operation. Make sure your devices are in a condition that allows them to be safely switched back on. Check that all unnecessary objects (e.g., tools) have been removed from the working area and that the equipment is in working order and that the controls are in safe operating mode (uncontrolled start). • Make sure everyone is away from your devices. Make sure any extra people are out of the area and let employees in the area know that the equipment will be switched back on.
11.	<ul style="list-style-type: none"> • The return of the security separation shall be carried out. In the order of the separation list, inversely

Signature of the person controlling the process: _____

Name clarification (and nickname): _____

Pseudonym	Nickname clarification	Pseudonym	Nickname clarification	Pseudonym	Nickname clarification
m		m			

--	--	--

Ready signature: _____

Name clarification: _____

The return of the safety separation shall be carried out in the reverse order to the one made. If the return must be made in another order, the order of return must be recorded separately.

5.2 Project reflection

The project's implementation and the thesis work overall necessitated the adaption of previously acquired competences and the acquisition of new skills and knowledge. As well as unfamiliar software and procedures, the project was carried out in a busy factory setting where noise disruption could be an issue, this was exacerbated however by working in a second language. The project, taken as a whole, was a strong example of safety-based work in the production and process industries; while much of the work was independent, assistance was readily available when needed.

The main difficulty of producing a project representation in thesis format was due to the sheer scale of the project and its time frame, in addition the company data sensitivity rules required the bulk of the detail to be a generalisation of standard practices, as opposed to complete depiction of the work and its outcomes. Managing to submit concrete evidence of the findings and eventual outcomes could be time consuming due to limitations on information sharing. The project is ongoing, and future work will be undertaken so as to adhere to the standards previously set out in the thesis documentation.

6 Conclusion

The ultimate conclusion can be of a successful project, documented to the best of ability, and conforming to not only workplace standards, but also the criteria set at the inception of the thesis project. The degree of research and coverage of all pertinent technologies allowed for

a reasonable level of practical implementation. The initial goal to review and improve on existing LOTO practices was exceeded as it became apparent that the previous procedures were undertaken on a case-by-case basis, with qualified personnel undertaking the isolation of hazardous energy points prior to maintenance and recording the process therefore no existing procedural standard was available to make functional comparison, as of the completion of the documented (Thesis procedure specifically) project, relevant isolation shutdowns will have a pre-emptive procedure available to appropriate personnel accessible from the internal database.

All applicable steps for procedural isolation shutdown were considered utilising the international standards as a guide, and the viability of the order of implementation discussed at length with operational employees. The procedure included within the thesis highlights examples of varying energy sources and the correct method of isolation, therefore the format of said document will be henceforth utilised as a base template the outline of which will underpin the creation of future procedures.

The finalized document will be included in an information dossier created through a companywide project designed to facilitate the ease of obtaining relevant information relating to safety practices during maintenance work, a pilot version of the project will be initiated in the winter 2023. The thesis commissioner has provided positive feedback. Based on the work completed during the thesis process, additional collaboration will be pursued with the aim of creating a database of safety procedures applicable to the entire workplace, which will be periodically evaluated for all pertinent machine maintenance protocols. The project can be deemed successful overall, as evidenced by the research and effective implementation.

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Appendix 1. Tervasaari Mill Presentation.



UPM Tervasaari mill - production

PM 5

- **Start-up:** 1938
- **Width:** 4.3 m
- **Products:** Glassine, release base papers for self adhesive laminates and tape end uses

PM 8

- **Start-up:** 1996
- **Width:** 6.4 m
- **Products:** Glassine and SCK's, release base papers for self adhesive laminates and tape end uses

Total designed capacity: 300 000 t/a

Management Systems:

- ISO 14001, ISO 9001, ISO 45001, ISO 22000

PM 5:

- Basis weight 55 – 120 g/m²
- 1 multiroll calender, 1 winder

PM 8:

- Basis weight 45 – 94 g/m²
- 2 supercalenders, 1 winder

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Power Plant

- Produces **process steam** and **electricity** for the paper machines
- Approx. one third of the required **electricity** is produced at the mill
- The **heat** required by the Tervasaari mill is produced by the mill's own power plant
- Heat is also sold to **external users** as district heating and steam. District heating of Valkeakoski is produced by the mill
- Biomass-based fuels 55 %
- Share of non fossil CO₂ fuels are > 65%
- Consumed electricity is 71 % total CO₂ free and 93 % fossil CO₂ free
- Heat energy is produced mainly with 2 boilers: one natural gas boiler and a solid fuel boiler

Water treatment, effluent treatment

- Water is needed for pulp manufacturing for paper and cooling the machinery and other equipment
- Water is taken from Mallasvesi lake
- Humus of the lake water is purified at the water station.
- After the production wastewater is treated
- Primary treatment: removes the solid losses from the water
- Biological treatment: purification takes place by microbes in the treatment plant's basins
- Best available techniques, BAT, are used for effluent treatment
- Excess bio sludge is pressed dry with the sludge from the primary clarifier to be incinerated at the power plant.

