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Statement Of Authenticity

"This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree."

Signed: *Owen Williams*

Date: 17/05/2024

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1.0 – Abstract

The following report investigates the process Enersys currently have in place to manufacture 20mm nuggets used to generate the plants oxide. The process has been highlighted within the plant as having a high expenditure compared to the output of product.

The process was identified as having a major part to play in rising energy bills for the company, along with this, the system was found to be a key factor in production downtime and late orders. This report shows the alternative processes that could be used, and how this can affect the overall company costs, and what other factors and areas can be improved with a changing process such as safety, health, and maintenance activities.

The report shows the alternative process identified as being the Cold Cube machine, this was found to provide similar if not better production outrates, as well as fully removing the gas supply of carbon dioxide (CO₂), methane (CH₄)/natural gas, nitrous oxide (N₂O), perfluorocarbons (PFCs) and Sulphur hexafluoride (SF₆); hydrofluorocarbons (HFCs). Further benefits are also found throughout the research such as removal of lead waste, health and safety benefits to the area and operators.

The report includes the decommission and installation of the old and new machines and what further work went into the project such as training, procedures, and maintenance. Tests were carried out and results were formed from operational results and running time and what further actions were needed.

2.0 – Introduction and Project Relevance

2.1 – Enersys Newport Plant

Enersys opened its plant in Newport in 1962 and currently supplies a wide range of stored energy solutions and systems to over 100 different countries and over 10,000 customers. The plant in Newport manufactures a variety of different size and power batteries all of which use lead and acid in the process. Enersys is recognized as the lead supplier of stored energy solutions. Enersys prides itself on buying in stacks of lead and then putting this through different processes in order to achieve desired outcomes for a wide range of products, different processes create different states of lead such as coils of lead, lead powder, lead paste.

2.2 – Nugget Casters and Oxide Mills

Each battery produced in Enersys includes the process where oxide is formed and then added to a mixture along with water, acid and sometimes carbon to produce a paste. Therefore, oxide is an integral part of the production of batteries and to form oxide, the nugget casters are needed. A basic flow diagram below shows the initial stages of manufacturing a battery with the area this report focuses on being clearly highlighted in the black box.

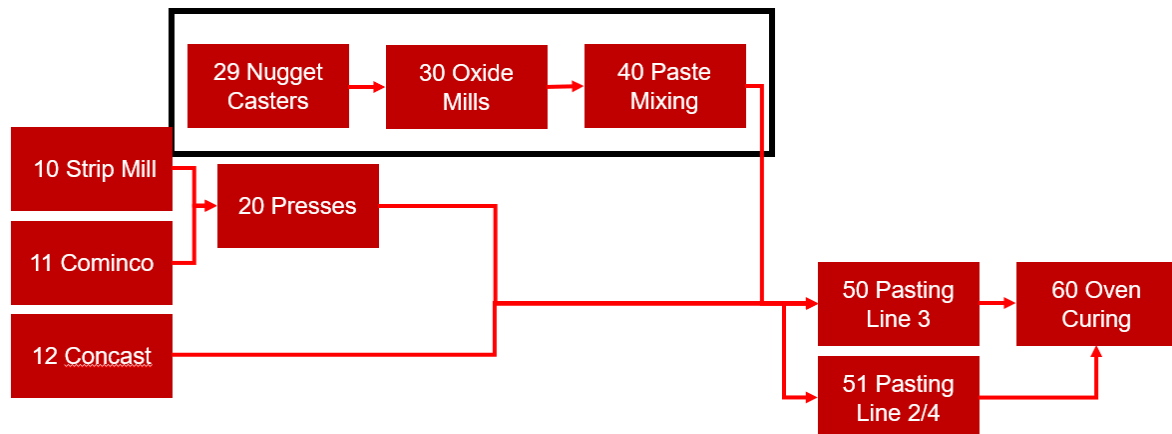


Figure 1 - Cell 1A + 1B Flow Diagram (Enersys P Drive)

To produce oxide, small 20mm lead nuggets are produced using a molten lead pot and a feed pipe which pours the lead onto a rotating table where rods are used to achieve the correct size. Once a complete rotation of the table has been carried out, the nuggets are cool due to the cooling water inside the machine and the compressed air-cooling bar. They are then pushed off the table using a simple cam system.

Currently in Enersys, the stats for the Nugget Casters are;

Shift Pattern: 3 Shift Pattern consisting of days, afternoons, and nights (8 hours).

Employees: 6 employees, 2 on each shift.

No of Machines: 3 nuggets casters feeding 4 oxide mills. Casters 2 and 3 feeding Mills 3 and 4. Caster 1 feeding mills 1 & 2.

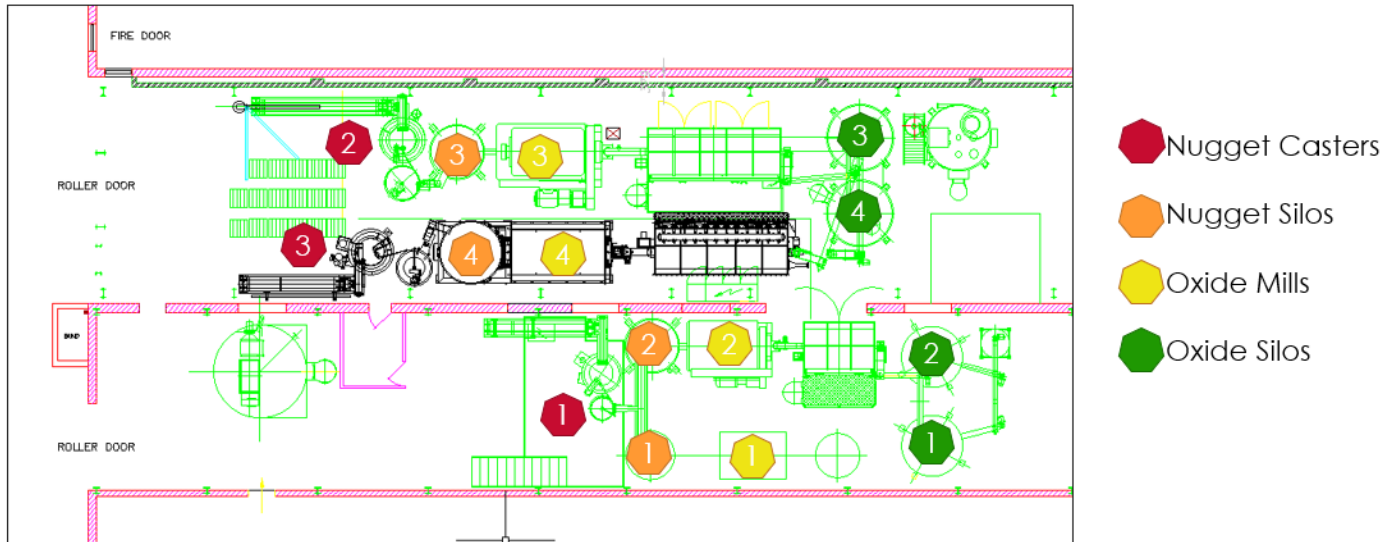


Figure 2 – Existing Floor Layout (Energys P Drive)

2.3 – Project Proposal

The project was assigned by the Plant Manager with the aim of trying to lower the overall annual energy costs. To identify the costs of running the machines, they were individually broken down and reviewed. Having found that the molten lead pots consume the most energy due to the gas they require, they were then compared and it was found that the nugget casting machine had the highest running costs. It was also found that there was an alternative machine which produces the same product without the use of molten lead. The project proposal is to fully remove all the current nugget casters and replace them with more modern machinery known as Cold Cubes. Modern technology development has changed the way in which lead nuggets/cubes can be manufactured. Along with technology development, energy bills have drastically risen with current affairs, and with the demand for companies to become more eco-friendly, a keen interest was taken in finding an improvement for the nugget casters, or possibly removing them all together. With further advantages such as safety, and personal health for the operators with the removal of molten lead giving off lead fumes, the removal of nugget casters could help play a crucial role in lowering the statistics for employees at Energys having a lead in blood reading greater than 15 20 µg/dl.

Cold cube machines use 50kg Ingots which are fed into the machine via a robot arm or suitable alternative, the ingots are then transferred along an automated conveyor to be processed into small 20mm cubes for the oxide mill process. They are processed by a blade cutting up the original ingot into small chunks, these are then formed using two rollers into 20mm cubes. Using two cold cube machines would generate enough production for the four oxide mills currently on site.

2.4 – Aims and Objectives

The main aim of doing this is to completely remove the molten lead pots and therefore remove the use of gas to lower the company's overall energy bills.

Further aims and objectives are to:

- Reduction in waste and processing costs.
- Lower the health risks for workers by reducing the lead in air.
- Remove the health and safety risks of lead casting.
- Reduce maintenance costs and downtime.
- Help lower percentage of late orders.

To achieve the above aims and objectives, relevant data needed to be gathered as well as thorough research into the current processes in place and what alternatives are available. This is to be carried out using analysis and measurement techniques with results being defined and critiqued.

To help collect a wider range of data and research, results and measurements were taken from sister plants where changes to their processes had already been completed, or where the same systems were being used.

3.0 – Timescale of Project

Timescale is a key aspect as to whether a project is a success or a failure. By setting appropriate deadlines and dates, it allows for motivation to be kept at a high, costings to not be affected (Cassidy, 2023). Carrying out techniques to set dates and deadlines can also highlight what tasks are critical to the project being delivered on time, these tasks can then be set a higher priority compared to other tasks

The main tool used for the timing of the Cold Cube project was a Gantt Chart.

3.1 – Gantt Charts

Gantt chart is a great tool to use to allow for tasks to be listed out, alongside a who is completing them and the deadline in which they need to be completed by. Using a simple colour scheme, jobs can be highlighted as being completed or late as well as helping to show what is critical for the project to stay on track.

Below is the layout of the original Gantt Chart made for the tasks consuming paperwork, research, and forms. It clearly identifies the task, along with the start and end date and the progress made. As seen from the visual progress on the right, the purple blocks show that the task is uncompleted.

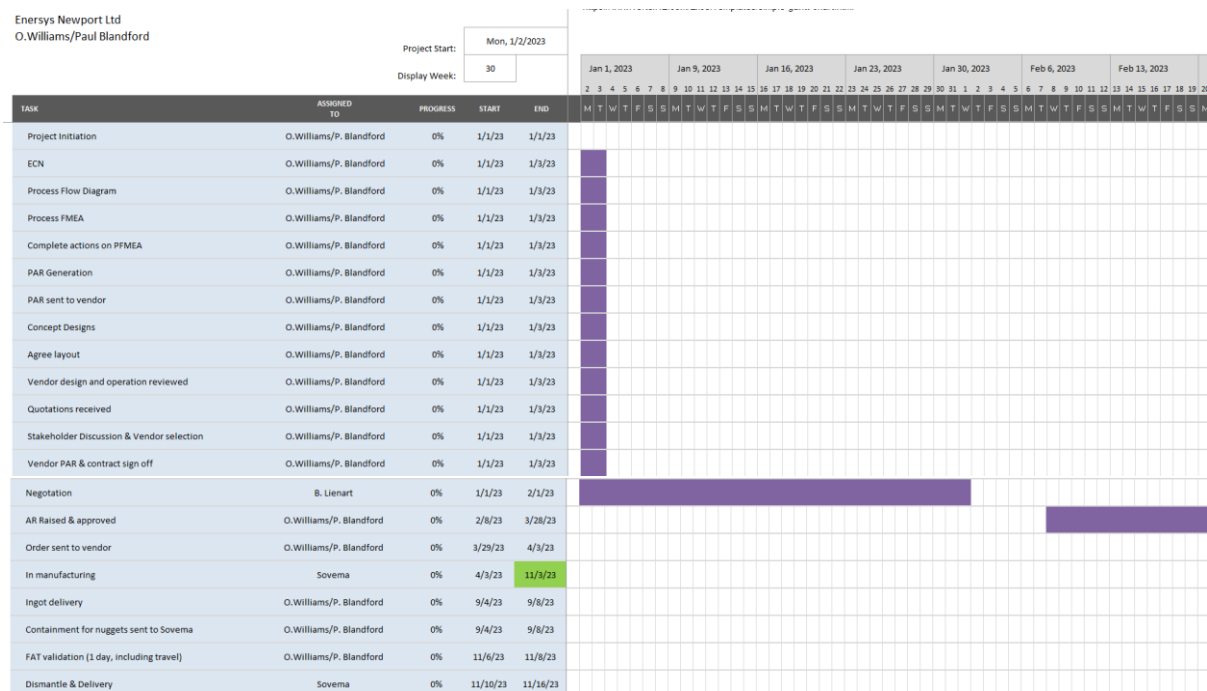


Figure 3 - Initial Gantt Chart for Requirements

Gantt charts were also used for the decommissioning and installation of the old and new equipment. It could be stated that this area was more important to set realistic targets as it included more outside employees such as contractors. Again, this is the initial design.

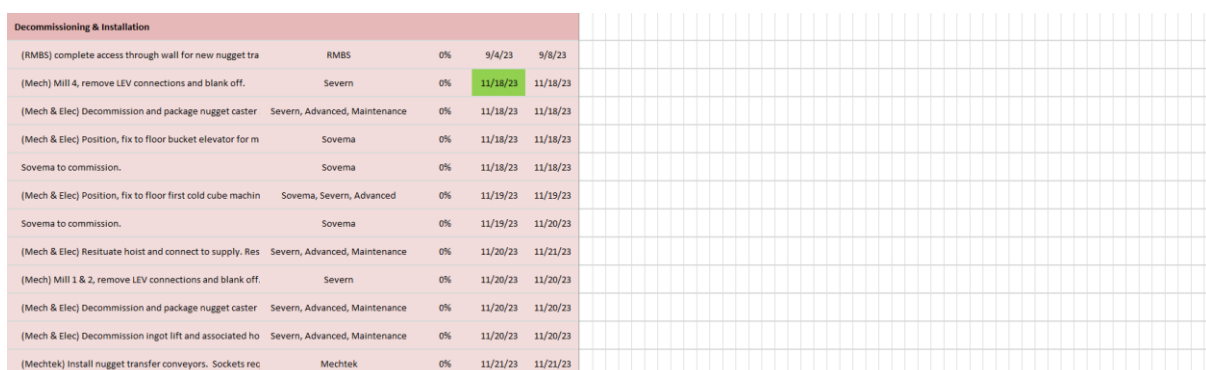


Figure 4 - Initial Gantt Chart for Decommissioning and Installation

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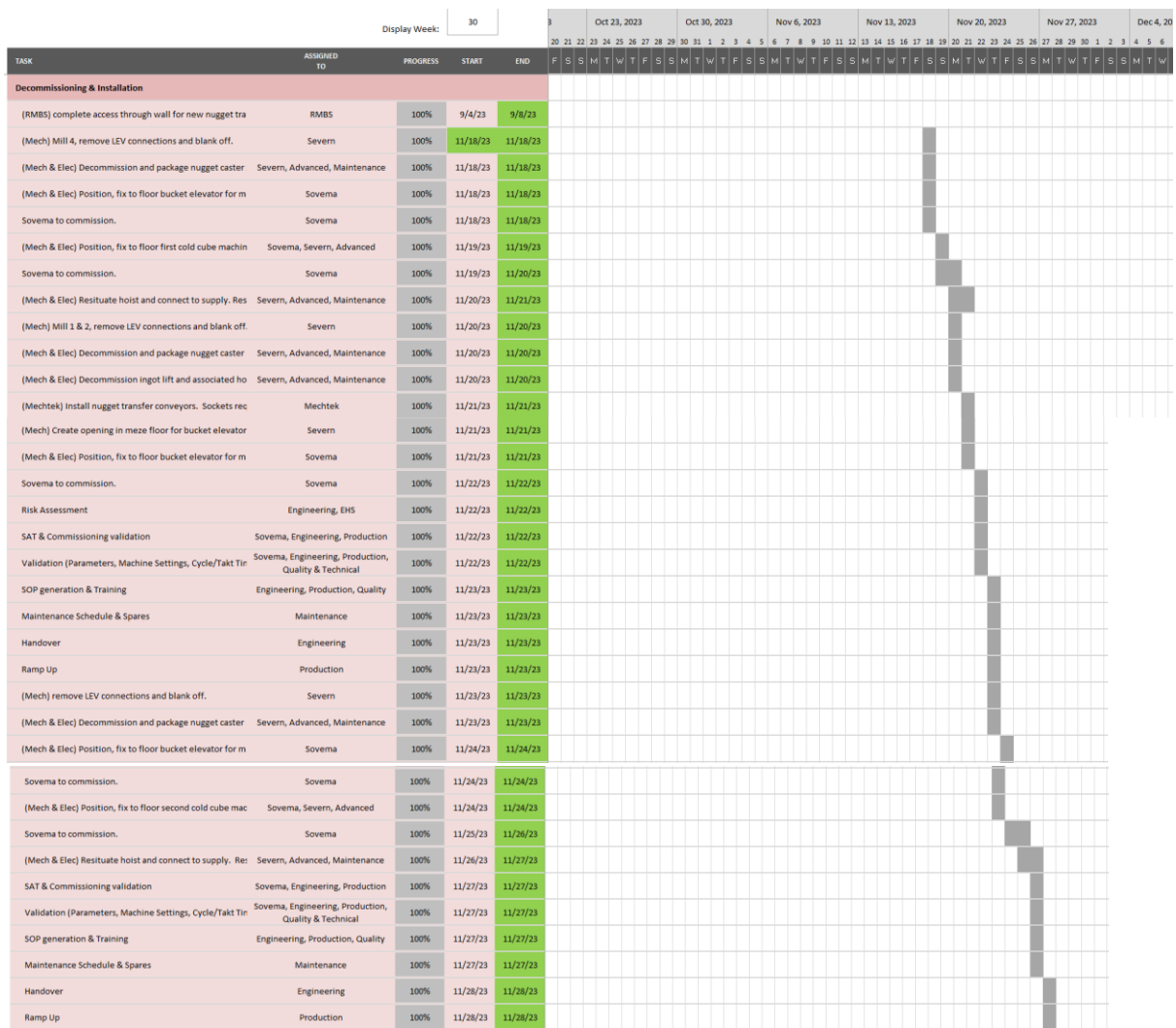


Figure 6 - Completed Gantt Chart for Decommissioning and Installation

4.0 – Research/Literature Review

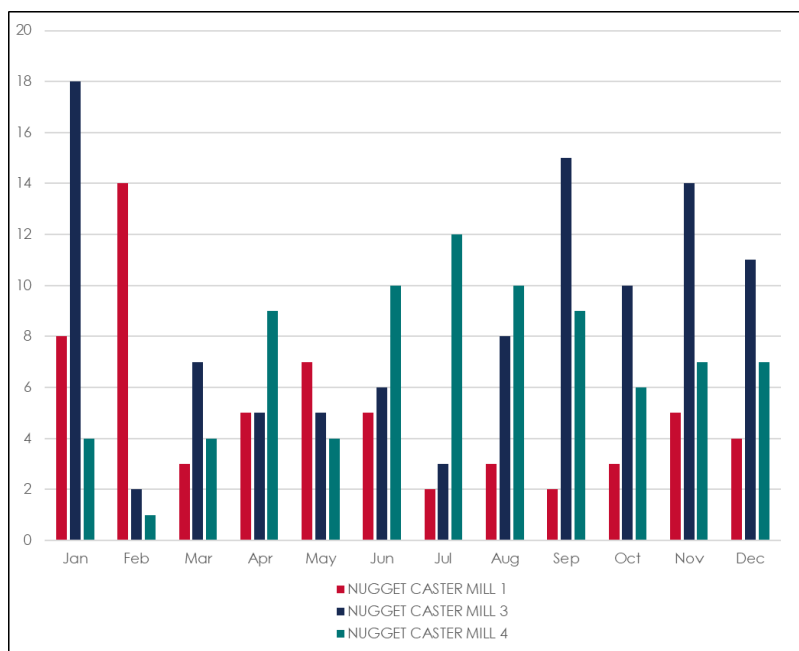
In any project, identifying the issue and researching this thoroughly is essential for success. Once the correct research has been done to identify the area or machine which needs improving, further research needs to be carried out to find the best solution.

Firstly, research was carried out to identify what machine on site has the highest running costs whilst having a more sustainable or possible replacement on the market. Once finding the identified machine, further research was to be done to find what the best solution is and what other areas would be impacted by changing or modifying the machine.

4.1 – Enersys Maintenance System

Enersys uses a maintenance management system called eMaint. eMaint is a reliable CMMs which allows companies to track maintenance workflows for equipment and assets. The software makes it easy to track work orders on specific machines, as well as history of jobs and keeping up a regular flow of preventative maintenance tasks (eMaint, 2024).

By having regular job logs on eMaint being composed by maintenance technicians, supervisors and engineering team, a thorough track can be kept of the number of jobs carried out on each machine, as well as the duration of each breakdown, and what process was carried out to repair the problem. Using this system, it was found that during the year 2022 there was a total of 248 work orders raised on the Nugget Caster machines, with an average breakdown keeping the machine down for 2 hours, this is broken down in the table below with graph.



	NUGGET CASTER MILL 1	NUGGET CASTER MILL 3	NUGGET CASTER MILL 4	Grand Total
Work Order Total	61	104	83	248

FY22 Nugget Caster Maintenance Labour Costs & Downtime			
Labour Cost/Hr	£		16.32
MTTR	Hr		2
Works Orders Raised			248
Maintenance Labour Costs (Not Including Contractual, Systems & Process Engineering Support)	£		8,094.72
Machine Downtime	Hr		496
	Days		20.7

FY22 Nugget Caster Maintenance Total		
Maintenance Labour Costs (Not Including Contractual, Systems & Process Engineering Support)	£	8,094.72
Maintenance Spares*	£	23,381.59
Total		31,476.31

Figure 7 - eMaint Data Collection

As the tables and data above show, Nugget Caster 3 had the most breakdowns and with the average breakdown lasting 2 hours, this shows the machine was down for around 8 and a half days. Along with this, maintenance facilitator (Warren, 2022) calculated a total cost £46,380 with contract costs on top. This identifies the Nugget Casters as having high running costs, due to number of breakdowns, length of downtime and costs to repair.

4.2 – Energy Costs and Usage

Recent surges in energy prices have made Enersys try to rethink how different machines can be used in specific processes to lower their current usage and expenditure. With a handful of machines on site using gas burners to melt lead, a focus was aimed at these machines as they are currently using the most energy.

(Ofgem, 2022) recommend that when calculating energy bills, to take the usage in kilowatts, and then use 70% of this to help calculate how much you have used. From average bills throughout the year 2022, it was taken that 522 kilowatts were being used a day for the three machines, then taking

70% of this gives 365.4. (Department for Business, Energy and Industrial Strategy, 2022) states that the current price per kWh during September 2022 was 4.76 pence, however it is predicted that by 2023 it will be up to around 7.5 pence per kW. Therefore, calculations can be made to see the cost per machine for gas alone for each hour, day and year as seen below.

FY22 GAS USAGE (Based on 70%, as advised by Energy Provider)		
Gas @ 70% (522 / 70%)	KW	365.4
Cost Of Gas/KWH	£	0.075
Cost Of Gas/Hr	£	27.405
Cost Of Gas/Day	£	657.72
Cost Of Gas Annually (machine x 350 Days)	£	230,202.00

Figure 8 - Gas Usage and Costs

From this further research can then be taken to find the electrical usage and cost for the three machines. Again, as taken from (Department for Business, Energy and Industrial Strategy, 2022) the price for electricity per kWh was 25.02 at the end of 2022, and from this the consumption was found per average bills, so calculations can be made for the cost for electricity. It needs to be noted that the 3 nugget casters, due to having molten lead needs extracts running above the pots to help remove the lead fumes, the cost of this was also taken into consideration as seen below.

FY Electricity Usage		
NUGGET CASTING	Cost Of Electricity/KWH	£ 0.25
	Machine Consumption/kWh	kWh 5.00
	Machines	3.00
		kWh 15.00
	Cost Of Electricity/Day	£ 90.00
EXTRACT A13	Cost Of Electricity Annually (350 Days)	£ 31,500.00
	Machine Consumption/kWh @ 50Hz Servicing all 3 pots & ingot caster	kWh 30.00
	Machines	1.00
	Cost Of Electricity/Day	£ 180.00
	Cost Of Electricity Annually (350 Days)	£ 63,000.00
TOTAL		£ 94,500.00

Figure 9 - Electricity Usage and Cost

As you can see from the above research and data gathered for the energy costs, the energy bills alone, to continuously run the nugget caster and the extract, is a total of £690,606 for gas alone as well as £94,500 for the electricity. The replacement or modification to the machines must lower the overall gas bill to achieve the main targets.

According to (Trading Economics, 2024), the rise of gas has been increasing since the middle of 2021 and during the middle of 2022 it peaked at 641.21 (GBp/thm), which is short for pence per therm. During May 2021 it was at 9.6300 (GBp/thm) which shows a huge increase, and with an emphasis on trying to reduce the amount of greenhouse gases and carbon footprint given off by companies, even though the current rate is at 70.7785 (GBp/thm), it is suspected that the price will increase again in the future.

4.3 – Health and Safety

Lead is a hazardous toxic metal that is found in multiple different products. Within Enersys, due to the production of lead acid batteries, exposure to lead is particularly high, with specific areas having strict PPE in place such as airflows, gloves, overalls to help protect health. Therefore, Control of Substances Hazardous to Health Regulations (COSHH) needs to be followed precisely, it states that;

the law requires the company to adequately control exposure to materials that can cause ill health. Most common routes of entry of lead into the body is through the inhalation of dust or fumes, and the ingestion of contaminated items (Heath and Safety Authority, 2002).

When high levels of lead enter the body, it can cause the organs to not function properly such as damage to the nervous system, kidney failure, blood disorders and cancer. Therefore, Enersys has a duty of care towards its employees. One of the many precautions in place is monitoring the lead in blood levels of the employees, HSE recommends that a blood test should be carried out at a maximum of 12 months between measurements when under 30 µg/dl. Enersys however carries out blood tests every 3 months, and having a result greater than 20 µg/dl means the employee must leave the lead exposed area.

(Bull, 2023) has stated in recent Enersys Bulletins, that the company's aim is to have every employee under 20 µg/dl. Removing the Nugget Casters which uses molten lead and therefore gives off high amounts of toxic fumes, will help reduce the employee's exposure to lead and help achieve the lead in blood targets.

Further health and safety improvements would include removing the nugget caster which is currently on a platform which could be exposed to lead spills. Having the 2 new machines would improve the floor space and therefore maintenance activities. Removing the molten lead process would improve the safety of maintenance activities, the new machines would come with a full safety circuit and interlocks making the overall system a lot safer.

4.4 – Lead Waste

With the use of molten lead, dross is formed as a layer on top due to the process of oxidation. When dross is formed, it must be scraped off and removed from the pots into waste bins, this requires our operators to manually remove and dump. The further issue with dross is that it is wasted and cannot be recycled or recovered on site. According to (WMA Enersys, 2022) 1,241 kg was being formed and wasted per week during the year 2022, with the average price per kg being £1.85 for the year, in total that is £119,384 in wastage costs formed from the three nugget casters.

4.5 – Cold Cube

The cold cube machinery is a modern concept designed and built by Sovema. Sovema is the manufacturer of all the Oxide Mills and Nugget Casters used at Enersys Newport, so having a developed machine which still suits the remainder of the process was a great advantage when collecting research as the company had a proven track record for lead processing products.

The Cold Cube machine is a simple design which takes 50kg ingots and feeds them automatically through a conveyor system which is operated by sensors and switches. Once fed to the guillotine the lead ingot is clamped using a pneumatic fed cylinder along with two pick up sensors. From here the ingot is released and moved under the cutting blade by 20mm and then re-clamped. A 20mm thick cut of lead is then taken by the hydraulic guillotine and the cut off is pushed down to the two forming rollers forces the off cut into multiple 20mm cubes through the mesh on the rollers. The cubes are then transported through conveyors and elevators to feed the selected silo.

With the system being fully enclosed with screening and viewing points, this means that access into the machine is only accessible by breaking the interlock circuit and therefore the system cannot run. Along with this, the use of only pneumatic, hydraulic, and electrical systems means that the need for gas is completely removed, whereby the target to reduce the energy bill for the company would be achieved. It also makes the machine and company more sustainable, the removal of the emissions of carbon dioxide (CO₂), methane (CH₄)/natural gas, nitrous oxide (N₂O), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆); hydrofluorocarbons (HFCs) means that the company is reducing its carbon footprint and becoming just slightly more eco-friendly. With the amount of gas worldwide being limited, (Oberfoi, 2022) states that with the demand for gas increasing and eventually the supply dropping, the prices are only ever going to increase; introducing machinery which removes the demand will help the company's future.

Having a new machine means a proposal and floorplan must be designed to gain an understanding of how they are going to supply all 4 oxide mills at Eversys Newport. Having the two Cold Cube machines next to each other will allow for only 1 operator needing to be present to operate them both reducing the number of operators required compared to the nugget casters. Below is the proposed floor plan.

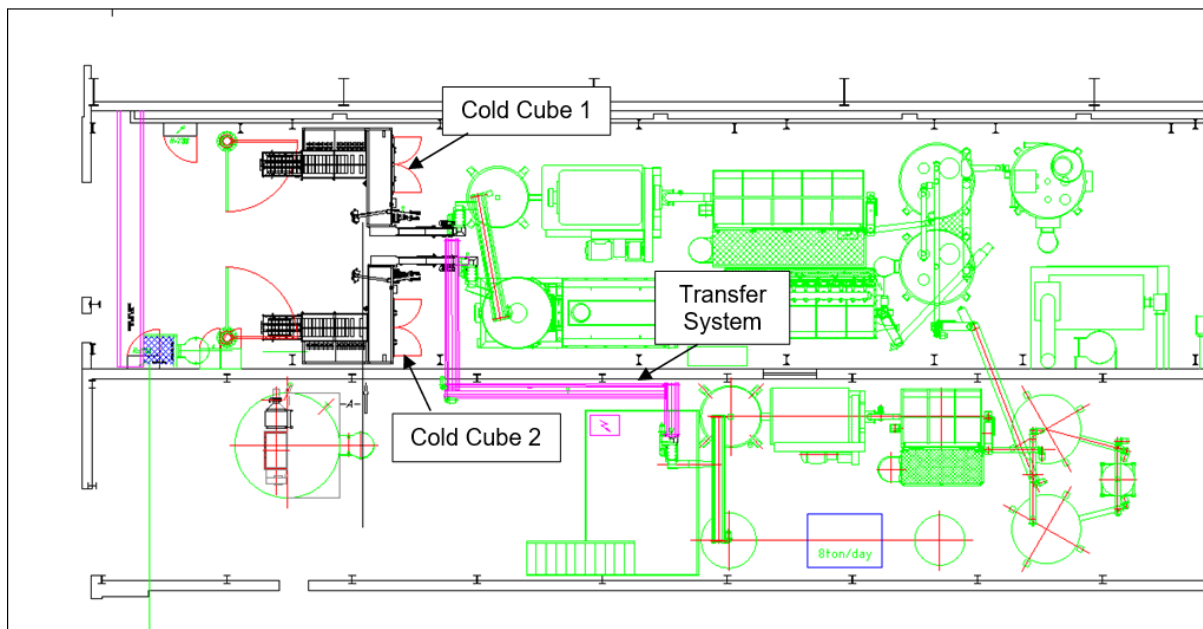


Figure 10 - Proposed Floor Plan

The proposed floor plan clearly shows the two cold cubes next to each other which can feed into their respective silos through a bucket elevator and also to each silo through a transfer conveyor. It also shows a transfer system made up of a series of conveyors highlighted in purple, this allows for lead cubes to be fed into the silos of Mills 1 & 2.

4.6 – Production Comparison

With the three nugget casters, one caster is slightly smaller than the others. Therefore, that machine produces less nuggets than the others. Saying this however, between the three machines and having two production operators running them due to the locations, the machines can produce up to

4600kg per hour, with casters two & three producing 1800kg each and caster one, which is on the mezz floor producing 1000kg. In a standard working production day, up to 47000 kg can be manufactured and therefore filling up to two silos ready for the Oxide Mills. This is represented on the basic table designed below.

Existing Nugget Capacity Output, Manning & Process Time				
Production Time	Hr	10.3		
Operator Requirement		1	1	
Machine Number		1	2	3
Nugget Caster Capacity, 1hr	Kg	1000	1800	1800
Nugget Caster Capacity, 1hr Total	Kg	4600		
Daily Production Capability	Kg	47150		

Figure 11 - Nugget Caster Production Output

When researching the potential production output of the Cold Cubes, tests had been carried out by Sovema who had supplied data and results. Results were also obtained and compared from a sister plant in Arras, France. The Arras plant had the Cold Cube system installed late 2022, so a good amount of research and data could be collected from here, along with the issues and opinions from maintenance and production.

According to (Sovema , 2023) providing that the lead ingots are to UNI standards, the Cold Cube machine can achieve out output of 2000 kg of lead an hour. With the plan to have two machines to replace the three casters, this would be a total output of 4000 kg of lead cubes an hour providing both machines run freely for the full hour. When comparing these results with Arras, they have stated that the maximum production they have made in an hour is 2400 kg, given the two machines this would be around 4800 kg an hour. The comparison can be seen in the below table.

2 Proposed Cold Cube Machines Output, Manning & Process Time		
Production Time	Hr	9.8
Operator Requirement		1
Cold Cube Machine, 1hr (Sovema Stated)	Kg	2000
Cold Cube Machine, 1hr (Arras Stated)	Kg	2400
Nugget Capacity, 1hr Total (Proposal, 2x machines)	Kg	4800
Daily Production Capability	Kg	47040

Figure 12 - Cold Cube Production Output

As you can see from both the tables, having the two cold cubes machines could produce 200kg more per hour compared to the three nugget casters. It has also got to be made clear that to produce the maximum number of nuggets, all three machines would have to be running and to do that, two operators would be needed due to the location of the machines. However, when looking at the cold cube machines, even if the stated production of Sovema is more accurate which means producing 600 kg less than the nugget caster, it only takes one operator to manage both machines due to the positioning of the machines being next to each other, and the fact the cold cube machine is more automated. This frees up an operator to carry out different tasks or jobs in other areas of the plant, which means the cold cube would also be more efficient with less production labour costs.

To make sure the amount of lead being processed per hour or per shift is accurate, it needed to be researched that the lead being delivered by the supplier is to the correct weight as stated. It is also

critical that the size and dimensions of the lead ingot is to tolerance, as if not it could cause issues with the machine, such as jam ups on conveyors or possibly the flipper table.

(Britannia Refined Materials LTD, 2023) stated in multiple loading manifest and advice notes that the delivered lead had a weight of 50kg per ingot. The delivery note stated that 560 ingots were on board the trailer with a combined weight of 28,060 kg giving a single ingot the weight on 50.1kg. When removing the lead, a calibrated weighing scales was used to weigh 10 random ingots from different batches, each ingot weighed was 48kg, therefore being 2 kg under the stated specification. This test was carried out on six different deliveries across the time span of a month, with each test giving the result of between 48 or 49 kg from the random ingots selected. From this, a calculation can be made that from the 560 ingots delivered and the random ingots selected all weighing 48kg, the delivery is 1,176kg underweight. This would also state that there could be a difference of nearly 200kg per hour of production due to the ingots being underweight by 2kg.



Figure 13 - Weight of Lead Ingot

LOADING MANIFEST & ADVICE NOTE NO. 335457		 Britannia Refined Metals Limited Solihull Road, Northfield, Birmingham, B37 7YU Telephone: 0121 714 53000 Fax: 0121 714 53003	
BRM Ref. No. 1141	Customer: EnerSys (Newport) (EH EUROPE GMBH)	Date: 26/04/2023	Time: 14:25
Deliver to: Stephenson Street, Newport, Gwent, NP9 0XJ	DRIVER MUST REPORT TO STORES BEFORE OFFLOADING COMMENCES	Quota Month: Contract No. 181.23.10015. -001	Job No. 300294
Ref.:		Sched. No. 203709	Haulier: SEACON
		Reg. No. 21	45015/6739
LOADS MUST BE SHEETED AND SECURED PROPERLY IMMEDIATELY AFTER SECURITY CHECK			
PRODUCT: Refined Lead (Pb min 99.99%)		WEIGHT (tonnes): 28.0600	
Lot: 3C48A	Type: 50kg (1)	Stacks: 28	
I hereby certify that I have received the above Tonnage (Nominal 560 pigs)			
Driver Signature: <i>Steve</i>		Customer Signature: <i>[Signature]</i>	
It is understood that sellers work weights are to be taken as final but in the event of a substantial difference being found on delivery, the matter must be reported immediately upon receipt and the full load set aside for reweighing.			
Checked by: <i>[Signature]</i>			
Britannia Refined Metals Ltd. Conditions of sale apply, a copy of which is available on request.			
EUROPE GMBH (EnerSys Newport) NOTE NO (N): 335457 		DOCK/GATE: DAP SUPPLIER ADDRESS: BRITANNIA REFINED METALS LTD. NET WT (kg): 28060 GROSS WT (kg): 43880 NO OF BOXES: 28	
PART NO (P):			
QUANTITY (Q): 28.0600 		DESCRIPTION: IPB9905A50 Refined Lead (Pb min 99.99%) SUPPLIER PART NO: 9905A 	
SUPPLIER (V): BRM 		PROD DATE: 27/03/2023 ENG CHANGE: 001 	
SERIAL (S/M/G): 300294 		BATCH NO (B): 3C48A 	

Figure 14 - Lead Supplier Delivery Note

Since the ingots are weighing below what is stated on the delivery papers, it would also mean that they do not match the required dimensions supplied for the ingot. (Britannia Refined Materials LTD, 2023) supplied the drawings below.

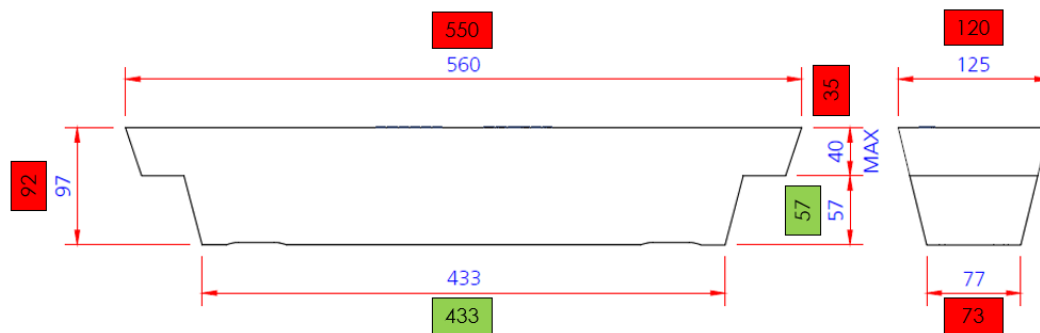


Figure 15 - Lead Ingot Dimensions

The numbers in the red boxes indicate the actual measurements taken from the tested ingots which were under what they should have been, and the boxes in green show the measurements that met the dimensions set by the supplier. This needs to be addressed as issues with dimensions can cause slowdowns in production and damages to the machine.

4.6.1 – Production Quality

When having two different processes which eventually produce the same output or product by the end of it, it is critical that no matter how different the machine and process is, the quality of the product at the end of the cycle is just as good if not better. This would obviously have a major impact on the overall outcome which would eventually be the batteries, however, having a different process for a product means that the product may have different material properties; this would mean that the oxide mills would have to have an adjustment to its settings to create the same quality oxide powder which was being produced using the nuggets from the caster.

To determine this, the same 30 tonne oxide mills were used, it's important to understand that the oxide mills have set parameters in place which allows the oxide to be processed at a set rate. (Battery Equipment , 2024) The oxide mill works by the nuggets or cubes being fed into a rotating drum, the friction created by the turning nuggets makes little lead particles because of the temperature created inside, which oxidises and forms the lead oxide. The depression created by the fan installed at the base of the filter generates an air flux, which transports the lighter lead oxide grains from the mill to the filter. Parameters put in place allow for the quality of oxide to remain whilst also achieving optimum amount of product during an hour or a shift, a change in parameters such as inlet depression, temperature, water consumption and feed amount will affect the production of oxide.

The below tables show the tests carried out by (Sovema , 2017). The top table shows the parameters used on the oxide mill when feeding the machine with nuggets produced by the nugget casters. This test was conducted over a series of four dates to generate a more accurate set of results. The table shows what the specific parameter should be at and alongside that what the parameters were for the machine whilst running. The same results were then carried out with the same parameters being set but with the oxide mill being fed with cubes formed by the cold cube machine instead. As seen from the results below, all the actual readings next to the parameters set are virtually identical and therefore can be said that the oxide mill performs the same achieving the same production quality and production rate with both cold cube product or nugget caster. Therefore, it can be stated that the Cold Cube production produces lead cubes which are to the same quality as what was being

produced before and so the quality of product doesn't get affected by the energy saving and safer option of process.

MILL 30 TON with CYLINDER CASTING

Date	Time	Inlet DP		MILL TEMPERATURE			FEEDING		FAN Hz	free lead	acid	water
		S.P.	real	S.P.	A	B	S.P.	real		%	absort.	absort.
03-11-2016	20:00	45	46	130	124	126	51	52.6	33.4	74.30	279	10.4
16-11-2016	04:00	45	44	130	125	127	51	52.5	33.5	71.64	280	10.3
01-12-2016	03:15	45	45	130	123	126	51	52.7	33.2	70.79	273	10.5
08-12-2016	19:10	45	46	130	124	125	51	52.7	33.1	74.79	287	10.5

MILL 30 TON with COLD CUBES PRODUCTION SYSTEM

Date	Time	Inlet DP		MILL TEMPERATURE			FEEDING		FAN Hz	free lead	acid	water
		S.P.	real	S.P.	A	B	S.P.	real		%	absort.	absort.
08.06.17	14:20	45	44	130	127	129	51	50.8	33.5	70.94	269	10.5
09.06.17	9:30	45	44	130	127	128	50	49.9	33.5	71.4	284	9.7
13.06.17	14:30	45	46	130	125	128	50	49.9	33.2	72.8	275	10.1

Figure 16 - Oxide Mill Performance with both Production Processes

4.7 – Cost Saving – Include buying Oxide straight

As stated above, the cost of running the Nugget Casters is huge and that is just on energy prices let alone the recent costs of maintenance downtime and spares. Costings also arise from the waste lead dross given off the molten lead pot. Obviously, with the removal of the molten lead pots will lower the energy costs due to the removal of the constant gas supply for the lead. As calculated above, during the year 2022 the three nugget casters cost £950,264 which includes the gas and electricity bills, along with dross wastage and maintenance costs.

Cold Cube maintenance costs cannot be compared to Nugget Casters due them needing to be run for around a year to understand issues, re-occurring problems, costs to repair and overall downtime. However, a rough calculation can be made for the energy usage for the year after implementation. According to (Sovema , 2023) the cold cube uses an average of 10.5 kWh, with the plan of having two machines this would calculate at £126 a day and then £44,100 a year, keeping the extracts to help reduce the amount of lead dust in area would give an overall cost of £51,450. Therefore, comparing this price with the costs of the nugget casters in 2022, would give an overall savings of £852,814 a year.

Another option would be to fully remove the need of creating the cubes or nuggets to form oxide, and just buy in oxide powder straight from a manufacturer. Enersys have done this from time to time due to manufacturing difficulties or product demand, they also continue to buy red lead oxide in powder form and do not manufacture that in house. Depending on what product is being manufactured throughout the week depends on how much oxide is needed, on average, around 80,000 kg of oxide is needed for the week. (Baker, 2023) gave information on the last purchase of grey oxide, a delivery of 25,000kg was made with the net price being £2,565 per 1000kg. Therefore, the total cost of this delivery was £64,125. With around 3 to 4 of these deliveries being needed a week, the total cost of buying in oxide would be extremely high. This is why Enersys take it upon themselves to manufacture the oxide themselves, as it is a much more sustainable and cheaper option.

4.8 – Failure Mode Effect Analysis

Failure Mode Effect Analysis (FMEA) is a systematic method used to help identify possible failures that pose risks to a specific process or machine (Juran, 2018). Using this on the Cold Cube machine can help find what possible problems could occur on the machine, how they occurred and what impact it will have on production and manufacturing demand. By using the FMEA structure, it helps visually see what issues or breakdowns are going to have the greatest impact and cause the longest amount of downtime. By identifying possible failures, systems and procedures can be put in place to help avoid such circumstances.

To calculate an overall score with the FMEA method, a number is given for the severity of the failure, the likelihood of that failure occurring and the severity or impact that failure would have on the machine or process. The score each of these is given is then multiplied together to generate the risk priority number.

As seen from the table below, most potential failures can be nullified and likelihood reduced by carrying out regular maintenance checks and tasks and having a sufficient spare parts list with access to all the parts which could be affected. Also having multiple sensors in the appropriate places can stop any issues from escalating and therefore causing more damage to the machine or individual parts. What lowers the score on some of the process parts is the fact that if a bucket elevator was to breakdown, the cross conveyors allow for each bucket elevator to feed other silos, so it does not fully stop an entire process, whereas damage to the forming rollers would stop the cubes from being manufactured, stopping production if down for a serious duration.

Process Step	Potential Failure Mode	Potential Effects	Severity	Potential Cause	Occurrence	Controls	Detection	RPN
Loading Ingots onto Cold Cube	Crane not lifting ingots onto chain. Chain not feeding Cold Cube.	Cold Cube machine cannot form cubes for Silos which feed Oxide Mills	8	Electrical or Mechanical fault with Crane/Chain	3	Regular maintenance checks and tasks to ensure components are in good condition.	2	48
Flipper table and feeding chains	Motor gearbox failure on seized chains	Cold Cube machine cannot form cubes for Silos which feed Oxide Mills	6	Ingot jam up causing overheating and wear	4	Regular maintenance checks and spare parts available always	3	72
Ingot clamping	Ingot not moving towards guillotine	Breakdown in production, or stoppage of production.	6	Misaligned sensor or low pressure of air.	4	Fault diagnosis screen on machine. Regular clean ups and spare parts being available.	2	48
Guillotine cutting the Lead Ingot	Not cutting ingot or damage to blade	Cold Cube machine cannot form cubes for Silos which feed Oxide Mills	9	Metal damaging the blade, or lack of pressure from hydraulic system.	2	Basic condition check of ingots upon arrival. Regular maintenance checks and tasks.	5	90
Forming rollers	No rotation of rollers or not forming lead	Cold Cube machine cannot form cubes for Silos which feed Oxide Mills	6	Sensor or drive issue. Oil on rollers causing lead to slip and not form.	4	Regular clean up of rollers. Maintenance checks and tasks, spare parts always available.	4	96
Feed conveyors	Specific conveyors not operating	Cold Cube machines cannot feed specific Oxide Mill Silos	4	Damaged belt, drive fault or sensor fault.	2	Regular maintenance check-ups. Cold Cube machines able to feed multiple conveyors.	2	16
Bucket Elevators	Specific bucket elevators not working	Cold Cube machines cannot feed specific Oxide Mill Silos	4	Damaged buckets, drive, or sensor fault	3	Regular maintenance check ups and spare parts always being available	3	36

Figure 17 - Failure Mode Effect Analysis (FMEA)

4.9 – Return on Investment

When researching for a project it is important to understand and find how long it will take for the investment to be paid back. So, having gathered various quotes from contractors for the cost of decommissioning, installing and design and build of various conveyors, the best deal and price can be looked at, and when finalised it can be added to the overall cost along with the machines from Sovema. These costings were collected and added to a visual table to see what the total costings would be.

Estimated Cost Worksheet				Document	ME350.3	version
				Total capital cost		\$711,504
				Total expense cost		\$62,047
				Total estimated cost		\$773,551
PLEASE USE THE SPACE BELOW TO SUPPORT ESTIMATED COST OF INVESTMENT. ALWAYS CROSS REFERENCE CAPITAL AND EXPENSE TOTALS TO AR FORM AND ME 350.7				* V = verbal, W = written and E = estimate		
Description of cost item	Source *	Capital (\$)	Expense (\$)			
Cold Cube Machines x2	W	\$489,714				
Installation Support, Mechanical	W	\$0	\$32,725			
Installation Support, Electrical	E	\$0	\$29,322			
Divert System (For Mills 1 & 2)	W	\$36,771				
Associated Systems Components	E	\$11,900				
Platform & Stairs	E	\$17,850				
Civils sample testing	E	\$7,140				
Mill 4 New cover/hood	W	\$21,400				
Mill 3 Chain guard replacement	W	\$22,470				
Mill 3 Outlet chamber	E	\$10,700				
Vibrating nugget feeder	E	\$7,490				
Lighting	E	\$16,050				
Painting (Wall & Floor)	E	\$16,050				

Figure 18 - Estimated Cost Spreadsheet

As seen, the collected total cost adds up to \$773,551 with a clear breakdown of how this total has arisen. When you compare this to our total costs spent in 2022 on the nugget casters being \$76,799 a month, when converted to dollars, from this a table can be drafted to help calculate the return on investment. The return on investment below just simply compares the investment next to the monthly expenditure seen on the last machines, the table below does not show costings or breakdown of the new machine as this cannot be accounted for yet, it also does not consider how much production output will be produced from the new machine. As seen, the payback on the investment is 18 months from installation, this is also supported by (Sovema , 2023) in the benefits of the cold cube.

Year 1	Feb 2023	Mar 2023	Apr 2023	May 2023	Jun 2023	Jul 2023	Aug 2023	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Totals
Incremental GP	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Cost Savings	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$38,390	\$76,780	\$76,780	\$76,780	\$76,780	\$345,510
Total Benefits	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$38,390	\$76,780	\$76,780	\$76,780	\$76,780	\$345,510
Investment	\$146,914	\$36,771	\$73,960	\$17,850	\$46,908	\$7,140	\$101,209	\$293,828	\$0	\$0	\$48,971	\$0	\$773,551
Cashflow	(\$146,914)	(\$183,685)	(\$257,645)	(\$275,495)	(\$322,403)	(\$329,543)	(\$430,752)	(\$686,190)	(\$609,410)	(\$532,630)	(\$504,821)	(\$428,041)	(\$428,041)
Year 2	Feb 2024	Mar 2024	Apr 2024	May 2024	Jun 2024	Jul 2024	Aug 2024	Sep 2024	Oct 2024	Nov 2024	Dec 2024	Jan 2025	Totals
Incremental GP	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Cost Savings	\$76,780	\$76,780	\$76,780	\$76,780	\$76,780	\$76,780	\$76,780	\$0	\$0	\$0	\$0	\$0	\$806,190
Total Benefits	\$76,780	\$76,780	\$76,780	\$76,780	\$76,780	\$76,780	\$76,780	\$0	\$0	\$0	\$0	\$0	\$806,190
Investment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$773,551
Cashflow	(\$351,261)	(\$274,481)	(\$197,701)	(\$120,921)	(\$44,141)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

Figure 19 - Return on Investment

5.0 – Work Done

5.1 – Decommissioning

Firstly, it was critical that when the decommissioning and installation of this project was to happen, that it did not affect production and that it would not cause orders to be late or machines to be down. To avoid this, the nugget casters and oxide mills were made a priority for the weeks leading to the schedule, before the planned implementation weekend, the aim was to have each oxide silo full, so having a total of 110,000kg oxide ready, and to have all the nugget silos full, 140,000 kg, so production would have enough product here to match the orders and the Cold Cube project would not affect them. It was also noted that the lead pots used for the nugget casters were to be run down to as low as possible to reduce the amount of total weight when being removed.

Before beginning the decommission, it is important that the electrical engineers and installers have a clear understanding of where the power is being fed from for the new machines. Once drawings have been made and clarified, the power can be safely cut off and isolated to begin removing the electrical supplies to the old nugget casters, elevators, and conveyors. It was found that the old electrical supply would be used for the new machine as it has the same power demand.

Once electrical supplies were removed and isolated correctly, the contractors started the removal of nugget caster 2 which supplies mill 4. Removing the lead pot, casting table and then the ingot infeed conveyor. Removing this machine first allowed for access to be made to cut out the section in the wall for the new conveyor to go through, which will eventually supply the elevators for Mill 1 & 2.

Next, the ingot lift and ingot conveyor were removed for the nugget caster on the mezz floor. The lead pot, nugget caster and bucket elevator then got removed using the same hoist and jib. After this was removed, the opening was made on the Mezz floor for where the bucket elevator will sit. Plates and covers were also fabricated to patch up the existing gaps and areas where old machinery was. Finally, the casting table and lead pot which supplies Mill 3 was removed, along with the ingot conveyor. All the old machinery was stored for the time being until approval to be scrapped, the bucket elevators for 3 and 4 were then removed.

Old cabinets and electrical supplies were disconnected and blanked off with the old cabinets being cut out and thrown away. Some electrical cabinets were moved and adjusted so that new machinery can fit in to place according to the new floorplan design.

5.2 – Installation

Firstly, the power supply was fed to each individual panel and the correct contactors, MCBs and cabling was used for each component, main isolators were also fitted. These panels were wired in accordance with the electrical drawings supplied by Sovema. Then, the first two bucket elevators were installed for Mills 3 and 4, these machines were then calibrated and commissioned by the Sovema engineer with power being supplied to the drives and sensors to detect rotation on the machines.

Then the first cold cube machine for Mill 4 was installed with the incline conveyor and infeed conveyor. They were then secured to the floor and connected to the power supplies, this again is commissioned by the Sovema engineer by installing the correct software and setting up the parameters and sensors to be ready for testing. The same process was then carried out on the second cold cube machine with it being fixed to the floor in accordance with the drawings and measurements.

Once the cold cube machines were installed, the Sovema commissioner engineer was engaged in setting them up ready for production. The mechanical and electrical contractors could carry on by installing the cross and feed conveyor. These conveyors will feed the bucket elevator for silos 1 & 2 for their respective mills, being in the next room means conveyors are fed through a wall and then up into the silo. Finally, the area was cut out ready for the installation of the final bucket elevator which was finally commissioned. All the power for these conveyors and bucket elevators were fed back to one main panel, whereas the cold cubes had their own separate control panels and power panels.

It is also vital that health and safety requirements are met at all times during installation and with the delivery of the machinery, it also must comply with regulations once installed and operating. These regulations are:

1. The supply Manufacture and installation of all plant and associated equipment will comply with the European Directive on Machine safety 2006/42/EC and will be CE certified and carry a CE mark.
2. All equipment must comply with the European Work Equipment Directive 2009/104/EC and 89/391/EEC.
3. The supply Manufacture and installation of all plant and associated equipment will comply with the European Directive 2006/95/CE – Low Voltage Directive.
4. The supply Manufacture and installation of all plant and associated equipment will comply with the European Directive Electromagnetic Compatibility Directive 2004/108/CE.
5. The equipment where possible must not emit noise levels greater than 80 dba when in operation and measured from outside the security envelope.
6. On Completion of installation / commissioning the work will be inspected and passed off by the Project team appointed by EnerSys Ltd Newport. Upon the plant being handed over a full set of documentation is required. These will consist of:
 - Certificate of conformity. (CE)
 - Complete technical file to meet the C/E mark requirements to be held by vendor.
 - All documents, both drawings (mechanical & electrical) and PLC listings will be in English.
 - The appointed Contractor will demonstrate to the Customer that the Contract is on time by producing a plan of time scales to include procurement of parts, installation time and commissioning. Review will take place on a regular basis to be agreed between customer and contractor.

5.3 – Testing

To test, the correct electrical drawings needed to be supplied, however this was obviously done at

the beginning of the decommissioning and installation as the cables and components need to be supplied with the correct power and feed the correct part of the machine. Once power is live and being supplied to each component, testing can be carried out by checking the correct voltage, current and power is being fed, and once E-Stops or interlocks are engaged, the power should be cut to isolate the process.

For the actual Cold Cubes, wiring diagrams were supplied by Sovema indicating where the power should be fed from, and indicating what is normally open, and what is normally closed. An example of that diagram can be seen below. This full book containing 42 pages of wiring diagrams for each single component of the machine along with how it is controlled by sensors, parameters, and sequences. Each of these pages was tested and checked before the system and machines could be tested in a proper cycle with production. When the correct checks had been made and parameters were in place, specific operations could then be tested by checking the manual screen on the control panel, this would check that the operations would work in manual and that not clear faults were present.

Safety circuits were a critical aspect which needed to be tested thoroughly on the machines installed. Having stated above that the installation of the cold cubes are much safer than the previous nugget casters, the safety circuit needed to be tested so that if a door is open, interlock is disengaged, emergency stop pressed, that all power is cut and nothing can be moved or operated, this would be done by causing a short in the circuit meaning nothing can be controlled unless that interlock is re-engaged, or emergency button is reset.

Once each component has been tested in accordance the wiring diagrams, and the safety circuit had been thoroughly tested along with the manual controls. The Sovema engineer can then set up the correct parameters for how the machine will perform during production and setting it up so the sequence is correct and each sensor is in the correct place to detect what it should be.

When applying a production rate to the machine, it was observed running in automatic with a constant feed of lead ingots for around an hour, this was to allow the engineer to observe the performance and then make the correct adjustments. The infeed rate was kept slow at the beginning just to check that the functions are working correctly and that there are no initial issues such as pneumatic leaks or hydraulic oil leaks. Once the operation of each component is working correctly, the production rate can begin to increase to the supposed hourly or daily output originally stated by Sovema. It is to be noted that production or operation of the machines is not to be carried out without the supervision or presence of the commissioner engineer.

 SOVEMA EQUIPMENT FOR LEAD-ACID BATTERIES A DIVISION OF SOVEMAGROUP			
via Spagna 13 - 37064 Villafranca di Verona - ITALY Tel. +39 045 6335711 - Fax +39 045 6303911 www.sovema.it - sovema@sovema.it			
MODELLO MODEL	COLD LEAD CYLINDERS		
MATRICOLA SERIAL NUMBER	6744 CE		
TIPO TYPE	COLD LEAD CYLINDERS		
SCHEMA ELETTRICO WIRING DIAGRAM	CU30	TENSIONE NOMINALE NOMINAL VOLTAGE	415 V
N° FASI N° PHASES	3	FREQUENZA FREQUENCY	50 Hz
CORRENTE NOMINALE NOMINAL CURRENT	55 A		
CORRENTE DI CORTO CIRCUITO - ICC SHORT CIRCUIT CURRENT - ICC	8 KA		
ANNO DI FABBRICAZIONE YEAR OF MANUFACTURE	2023	PESO WEIGHT	Kg
RIFERITA A REFERENCE TO	EN60204-1 IEC60204-1		

RELEASE	rev 8 - 06/10/2023	DATA	21/04/2023	 SOVEMA EQUIPMENT FOR LEAD-ACID BATTERIES A DIVISION OF SOVEMAGROUP	CUBETTATRICE	CUSTOMER:	FOGLIO 1 SEQUE
COMMESSA	13001236	DESIGNER	V.N.		COLD LEAD CYLINDERS	ENERSYS UK	FOGLI TOTALI 40
MATRICOLA	6744 CE					N° DISEGNO: CU30.DWG	

Figure 20 - Sovema Wiring Diagram Opening Page for Enersys

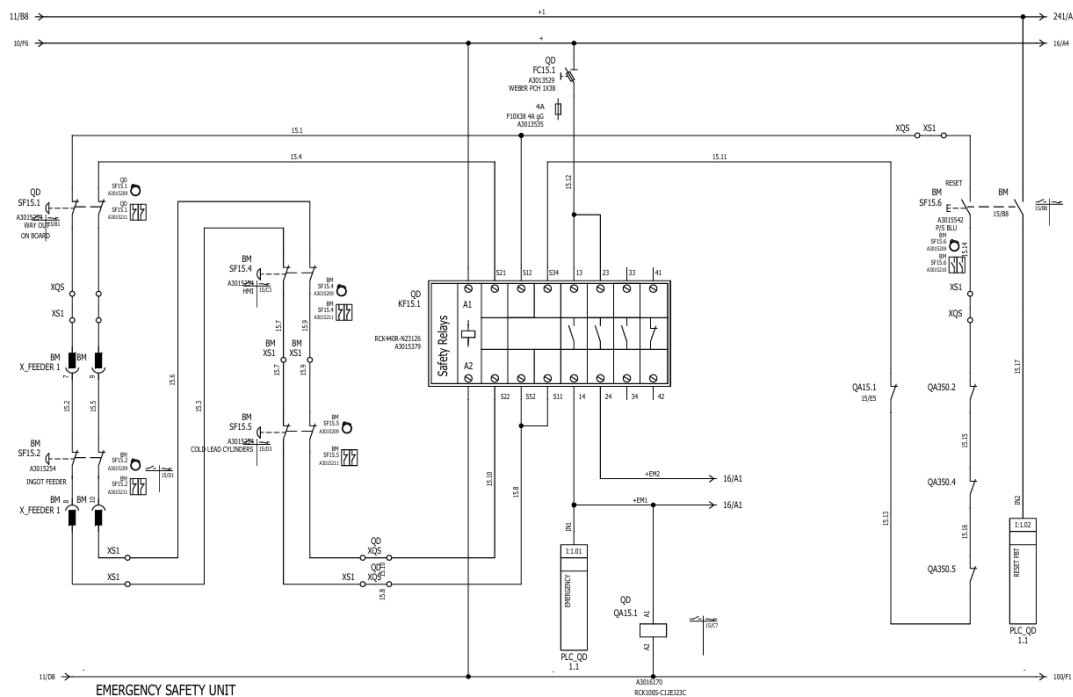


Figure 21 - Example of Wiring Diagram followed

More diagrams including pneumatic drawings can be found in the Appendix 5.3.

5.4 – Training

When introducing a new machine to a company or plant, it is critical that appropriate training is provided to all employees involved with the cold cube machine, such as, specific operators, maintenance personnel, engineers, supervisors, and managers. Providing the correct training on how to operate the machine, and how to maintain it is critical in achieving the greatest output and minimising downtime and breakdowns.

To be prepared for when the machine is installed at Enersys, Newport, consistent trips were made to the sister factory in Arras which had the Cold Cube machines already fully operating. Trips were also made to the Sovema factory in Italy, here the manufactures of the machines could explain in detail how to properly operate the machine, as well as possible issues or alarms which may occur and how these can be rectified. These trips were made to the factories between August 2023 and November 2023 just before the installation, this allowed for the operators and maintenance to have a better understanding of the machine when it was fully installed and running.

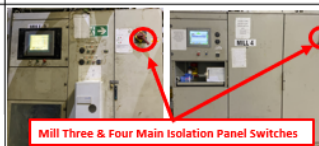
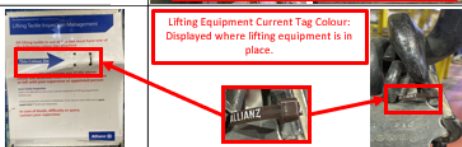
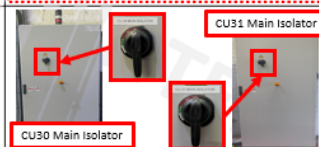
Basic training was provided such as common alarms, their meaning and what needs to be done to clear the fault. This would often include sensors not being made, or misalignment of ingots. Often these faults can be cleared by cleaning the sensors, or manually operating a specific performance, this was shown to all operators and maintenance personnel, operations and PLC's programs were also shown and explained to engineers to gain a greater knowledge of the machine. Having a good training scheme and schedule in place will help reduce the number of breakdowns caused by the operators not being fully embedded with the machine. It will also allow the maintenance staff to

fault find and repair the machine at a faster rate knowing what the problem is, where it is on the machine and what needs to be done to repair it.

5.5 – Maintenance Procedures

Undertaking maintenance tasks on any machinery comes with hazards and risks, it is vital in industry that these hazards and risks are identified, and then procedures and structures are put in place to reduce them and reduce the likelihood of these occurring.

Having maintenance procedures in place on each individual machine allows for maintenance personnel to have a clear understanding of where isolation points are, how a specific job can be made safer and how it should be properly carried out. It also indicates what personal protective equipment should be worn in that area. When undertaking a task in the cold cubes a risk assessment should be carried out before completing any tasks. The below tables are known as an SOP or standard operating procedure, where it breaks down the process and shows where individual isolators are located and what they are isolating. SOP improves the safety of the working environment by identifying and minimising risks and hazards, it also reduces costs and improves productivity as it allows personnel to carry out tasks in a reduced amount of time, therefore allowing production to restart quicker.

		Task Description	Isolation Procedure	Author:	Owen Williams	Issue Date:	Click to add text
		Plant Procedure No:	Click to add text	Approved By:	Click to add text	Revision No:	SEE FOOTER
		Plant Location:	Oxide Mill 3 & 4	Area Owner:	Click to add text	Review Date:	Click to add text
		Responsible Person:	Authorised Personnel	Frequency of check:	When carrying out maintenance	Compliance assured:	Click to add text
Step:	Major Step	Key Point Reason: Safety Quality Environment	Key Safety Criteria		Visual Aids / Supporting Images		
#	Scope of Work: Isolation of equipment prior to taking out any form of Maintenance activity:	1 Prior to working on any equipment in the Oxide Mill a risk assessment must be completed.	When working on any equipment in the Oxide Mill the Main Isolator and Local Isolator must be locked off. If not possible to isolate the Main Power source then the Local Isolator MUST be isolated.	No work is to be carried out unless as a minimum action the Local Isolation Points have been locked out and any stored power has been exhausted.	 Mill Three & Four Main Isolation Panel Switches		
	Incorporating: Preventative, Remedial & Reactive maintenance activity, process modification and any planned or unplanned cleaning activity.	2 Only authorised personnel are allowed to complete any maintenance activity including the clearing of blockages. Following the LOTO procedure (OPS431) at all times.					
	General Note: Lifting Equipment	When using the Overhead Crane to Lift/Lower machine parts e.g. Machine Parts/Drive Motors etc. Ensure the lifting equipment is tagged in accordance with the colour code system stated in the Lifting Tackle Inspection Procedure.	Ensure the working area and transport route is clear prior to lifting any equipment. Ensure lifting equipment is in good order and load is secure prior to attempting to lift.		 Lifting Equipment Current Tag Colour: Displayed where lifting equipment is in place.		
1	Load Ingots (CU30/CU31)	1 When working on the hoist, isolate Locally.			Maintenance Note: Both Cold Cube Processes CU30 and CU31 are designed to be run independently. Each Unit has it's own Control Cabinet and Air Supply which MUST be isolated independently. Units CU30 and CU31 are not designed with Local Isolation, each module can be unplugged from the main power source. Isolate using the Respective Control Cabinet Main Isolator		
		2 Ensure the hoist is in a safe working position prior to conducting and maintenance activity.					
2	Lead Ingot Transfer Conveyor including Ingot Turnover Mechanism and Ingot Transfer Conveyor to Cube Cutter (x2 CU30/CU31).	1 When working on the Ingot Transfer Conveyors and Turnover mechanism isolate using the relevant process (CU30/CU31) Control Cabinet Main Isolator.		Note: Main Isolation Point MUST BE USED.	 CU31 Main Isolator CU30 Main Isolator		
		2		Inform Mill Operator of presence when working in the area.			
		3 If releasing a conveyor jam, beware of any potential stored energy.					
Standard PPE		Chemical Hazards	Non Standard PPE				
							
			Kevlar Gloves				

Page 1 of 7

Figure 22 - Cold Cube Standard Operating Procedure (SOP)

The remainder of the Standard Operating Procedures can be found in the Appendix section of 5.5.

These procedures should be followed at all times and followed for every maintenance task, whether this is a reactive maintenance job or a preventative maintenance task. It should be noted that lock off tag off equipment is to be used, this is available to everyone with personal equipment and a communal board which supplies the correct equipment.

Risk assessments are also a critical part of maintaining safe working practice within a company or an area of a plant. As recommended by the standard operating procedures above, activities on the Cold Cube require risk assessments to help reduce the risk and hazards that can occur, and being a new machine, it is important to become aware of the potential issues straight away. This decision-making tool aims to determine which measures should be put in place in order to eliminate or control those risks, as well as specify which of them should be prioritized according to the level of likeliness and impact they have on the business. Risk assessments were created for general maintenance tasks on the Cold Cube machine and should be understood and followed at all times.

Carrying Out General Maintenance activity on the Ingot Conveyors	Entanglement in Machine Moving Elements	Maintenance Operator	Electrical Isolation procedure in place (LOTO). Main Isolation to be used.	4	2	8	Tolerable Risk	No Recommendations/Actions
Carrying Out General Maintenance activity on the Ingot Conveyors	Being struck by Elements which exist in the area (e.g. Ingots/Crane Jib)	Maintenance Operator	Only fully trained operators to operate the crane. Maintenance Operator to communicate with Mill Operator of presence in the area. Crane has 3rd party servicing.	4	2	8	Tolerable Risk	No Recommendations/Actions
Releasing a Jammed Ingot on the Conveyor	Trapped/Crushed Limbs, Fingers/Hands	Maintenance Operator	Electrical Isolation procedure in place. LOTO procedure in place. Manual Handling Training. Process related training. Dynamic Risk Assessment.	4	2	8	Tolerable Risk	No Recommendations/Actions
Carrying Out General Maintenance activity on the Ingot Conveyors	Struck by machine parts when lifting using the Crane.	Maintenance Operator	Process related training, load slinging/securing training, lifting tackle inspection procedure. Crane has 3rd party servicing.	4	2	8	Tolerable Risk	No Recommendations/Actions
Carrying Out General Maintenance activity on the Cube Cut Process.	Slips, Trips & Falls	Maintenance Operator	Appropriate PPE. Ongoing Housekeeping Activities, through the TPM programme & floor demarcation. Hand Rails. Suitable Lighting. Dynamic Risk Assessment to be completed if conditions vary from the standard.	3	3	9	Tolerable Risk	Damaged and uneven floors to be repaired and coated. Steps and Walking Gantry's to be installed.

Figure 23 - Cold Cube Risk General Risk Assessment

Further risk assessments of the new machinery and surrounding area can be found in the appendix 5.5.

5.6 – Preventative Maintenance

Preventative maintenance is the act of performing scheduled maintenance checks regularly to help prevent unexpected breakdowns or failures within specific components. Using the company's online maintenance page, creating the maintenance tasks means that eMaint can notify the personnel when specific tasks and checks need to be carried out.

To generate proper preventative maintenance tasks, the Cold Cube machine was split up into specific sections, this means that thorough checks can be carried out on each individual component whilst

not keeping the machine down for a long duration of time by checking every component at once. Carrying out these preventative maintenance tasks makes the Cold Cube more reliable by extending the lifetime of each asset whilst also reducing the amount of maintenance and downtime, therefore production output can be achieved on a more regular basis and costs can be kept to a minimum.

It is also important to understand that components can be over-maintained. By this it means that bearings, or slides can be greased too much which eventually causes them to fail, so, understanding the parts on the machine means that the preventative tasks can be set to a suitable timescale for when they need to be carried out, this is known as Calendar/time-based preventive maintenance. Calendar/time-based preventive maintenance occurs at a scheduled time, based on a calendar interval. The maintenance action is triggered when the due date approaches and necessary work orders have been created, this is done using the companies eMaint page.

When creating the preventative maintenance tasks each one differs. So, as the chains are high weight bearing these are more frequently checked for damage and issues. Typically, the bearings are checked and lubricated every two weeks to a month depending on where they are. Safety checks such as interlocks, emergency stops and guarding is checked weekly by maintenance, but daily routine checks are carried out by operators at the start of the shift before running the machine. The preventative tasks assigned must be easy to understand and read and clearly identify what checks needs to be carried out and what safety processes need to be carried out before starting the task.

Work Order							
Work Order No.: 64331	Open / History: O						
Work Order Date: Monday, 29 Apr 2024	Work Order Status: Open						
Work Order Time: 01:43:52	Work Order Type: PM						
Asset ID: EC1-15-010-010	Problem Type:						
Asset Description: Cell 1B - Cold Cube CU30 Ingot Loader	Completed Date:						
Building: Cell 1B	Time Completed:						
Parent Asset ID: EC1-15-010	Supervisor Priority:						
Parent Asset Description: Cell 1B - Cold Cube CU30	Project #:						
Request #:	Sched. Date:						
Requested By: P.M. Schedule	Est. Hours: 2.00						
Assign To Type: Employee	Req. E-mail:						
Assign To: (Cell 1 Mechanical Fitters)							
Work Order Title: Cold Cube - Ingot Conveyor Inspection - 4 Weekly							
> Supporting Documents Page 175 of COLD LEAD CUBES PRODUCTION SYSTE Isolate Machine before commencing work and follow company LOTO procedure (OPS431). Inspect drive chain for signs of wear. Inspect gearbox for damage and oil leaks. Check gearbox mounting bolts are tight and locked in place. Check tension on drive chain, adjust where necessary. Check drive sprockets for signs of wear. Check tension of ingot carrying chains, adjust where necessary. Inspect main chain sprockets for signs of wear. Check condition of bearings. Ensure all bolts and grub screws are tight and locked in place. Once completed, remove isolation lock and enable power on to machine. Hand machine back to operator or area supervisor. Report findings to Maintenance Supervisor or Engineering	Work Request or Work Order Photo:						
Work Order Feedback: Work Order Closed By:	Insp. Round WO#:						
<table border="1"> <thead> <tr> <th>Part numbers</th> <th>Description</th> <th>Location</th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> <td> </td> </tr> </tbody> </table>	Part numbers	Description	Location				
Part numbers	Description	Location					

Figure 24 - Example of Preventative Maintenance Work Order

6.0- Results & Final Testing

6.1 – Final Testing

Having carried out initial testing to make sure the operation of each component functions properly and works correctly both in manual individually and once in a sequence, full commissioning can then be completed. It has been agreed that once fully installed each Cold Cube machine must satisfy the site acceptance run, this will be when the machines operate for a full 8-hour shift without any stoppages or faults, the production rate of 2 tonne per hour must be achieved at a minimum, this would need to be achieved on three separate occasions throughout the week of commissioning. It was also made clear that the machine would not be operated without the supervision of the commissioning engineer so if a fault does occur, it can be explained why this has alarmed and what actions need to be taken to rectify the fault.

Final testing also included how the machine would perform and operate when the Sovema engineer leaves and the machine is left in the hands of Enersys and the operators, this would mean the Cold Cube being operated around 20 hours a day for five or six days a week until the silos are full with lead cubes, this test would be conducted over the next month after installation and commissioning and would show what common faults or downtime occurs and what action needs to be taken.

6.2 – Results

From the commissioning results it was clear to see that both the cold cube machines could operate at the production rate of 2 tonnes per hour, showing that all the individual components work and work together in a sequence. When the machines were operated with just Enersys employees, several issues and faults did re-occur over the coming weeks, it was evident that these breakdowns were occurring due to the personnel not being fully embedded with the machine, so issues which could easily have been avoided were occurring.

Firstly, due to the different sizes of ingots being delivered, it means the flipper table sometimes needs to be adjusted in height, for this there is a driving wheel which moves the forks upwards or downwards depending on where you need them. However, when driving the flipper table forks upwards it was found that it can be over-driven which would cause the ingot detection sensor to make contact and in multiple cases snap off. Action was taken to and the position of the sensor was moved so that it would still detect that an ingot was present in the table but if the flipper table was over-adjusted it would not break the sensor.

Another occurring issue which happened multiple times was damage to the buckets on the bucket elevator. Damage to the buckets causes the lead cubes to drop back to the bottom on the lift and means the operator needs to keep re-feeding them back into the elevator. It also causes the machine to become particularly noisy and will cause the machine more damage. It was found that Sovema had not used anti-vibration nuts on the bottom guides causing them to work loose and jam into the buckets damaging them. These slides and buckets were replaced with the correct vibration nuts used.

Since the installation of the machines, it was known from research and data that the overall energy bill of the company would decrease due to the removal of gas consumption. Breakdowns have been

limited and even when it has often been small issues such as dirty sensors or jammed up conveyors due to ingots. Bigger breakdowns such as the buckets on the bucket elevator have been under warranty. The supplier provided a warranty that the equipment shall be free of defects in design, materials or workmanship for 12 months following on site commissioning. All costs associated with repair or replacement because of failure of the equipment will be borne by the supplier. In line with the agreed contract.

In the 5/6 months which the Cold Cubes have been fully operating it has also been noted that the nugget silos are now continuously full and therefore production further down the line has not been affected nor have orders been late due to limited oxide manufacturing. This is due to the machines producing the desired output of a minimum of 2 tonne an hour each shift. Overall lead in blood levels of the operators have also dropped with there now being no personnel working in the area having results greater than 15 µg/dl, which is working towards the end of 2024 target of no employee being above this number.

7.0 – Conclusion

To conclude, the aim at the beginning of the project was to identify what machine had the biggest energy consumption. After narrowing it down to the nugget casters along with other major factors it was important to find whether an alternative machine was available on the market. Having found the Cold Cube machines presented by Sovema, it was critical that detailed research was carried out on both the current machine and the identified replacement. Covering every area of the new machine with research allowed for a greater knowledge and understanding of how it operates and would help deliver a successful project with no surprising pop ups or major issues.

Having completed the essential paperwork and following the timescale set using the Gantt Chart, it allowed for deadlines to be followed and achieved. The research then indicated what can be expected from the Cold Cube machine as well as showing the money saved due to the removal of gas and removal of molten lead. Removing the molten lead also has great health and safety improvements not just for maintenance jobs but for operator tasks as well.

Since the decommissioning and installation, the Cold Cube was then put through a series of testing both electrically and mechanically, checking circuits, safety features, operation, and functions of individual components. Once satisfied with the performance of each part, further testing was undertaken to test the system works in sequence and then put under test to run for a full shift to see if it produces the required output of 2 tonne an hour.

The Cold Cube machines and transfer system have now been operating for 5 to 6 months and it is clear to see that production output is as stated at around 2 tonne and hour or greater. There has been a limited amount of breakdowns and only major downtime has been with the bucket elevator where the issue was resolved with no cost due to the machine being under warranty. Other issues have involved operator error due to them not being fully embedded with the new machines. Having sufficient and appropriate preventative maintenance tasks in place has allowed the components to maximise their asset lifetime whilst improving the productivity and reducing the breakdowns.

Overall, the Cold Cube project has achieved the goals it set out to hit by reducing energy cost whilst improving health and safety, outstanding costs such as waste and keeping up with the demands on production continuously. Over a sustained period, such as a year it can be determined whether the

new machines have become easier to maintain and if the number of breakdowns and duration of downtime has also decreased.

8.0 – Recommended Further Work

After carrying out a project it is important to review the work carried out and then try to identify what further work needs to be carried out. After carrying out the general risk assessments on the Cold Cube it was identified that areas of the floor surrounding the machine was uneven and therefore prone to trips and slips. It was also raised that steps and a handrail should be fabricated and installed around the incline conveyors for easier and safer access. Fitting this along with laying a new resin floor will reduce the likelihood of hazards and risks arising in the area that were identified from the general risk assessment.

It has also been recommended that a gantry crane is to be installed above the new machines in order to make it easier to lift and remove heavy components on the machine if needed. Again, by installing a gantry crane it will improve the safety of the area whilst lowering the chances of an accident or incident occurring such as strains and muscle pulls. The crane would need to follow Lifting Operations and Lifting Equipment Regulations (LOLER) when installed and training or top ups would have to be provided to maintenance employees in order to understand the regulation and how actions or tasks involving lifting equipment is to be carried out safely.

Further work may be needed within the next few months as the workers gain more knowledge and understanding of the machine. This may require movement of sensors for improvement of positioning due to obstruction, or modifying plates or guarding if needed, this will become apparent after a longer duration of operation.

9.0 – References & Associated Personell

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Personell Associated with Project

Plant Manager – Timothy Gibbons

Senior Project Engineer – Paul Blandford

Engineering Manager – Paul Herbert

Maintenance Manager – Steve James

Controls Engineer – Morgan Peters

Process Engineers – Dave Hockey & Julian O’Connell

Maintenance Supervisor – Geraint Smith

Production Manager – Glen Murdoch

Health & Safety Manager – Jeff Bull

Quality Manager – Andre Barni De Azevedo

Supply Chain Manager – Jayne Gibbon

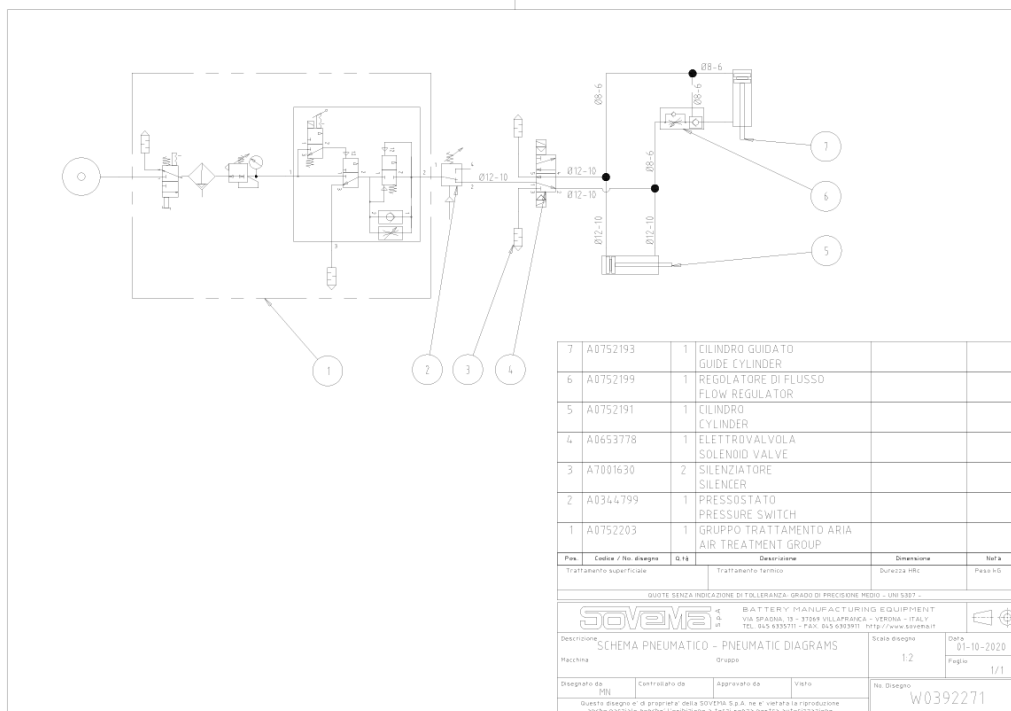
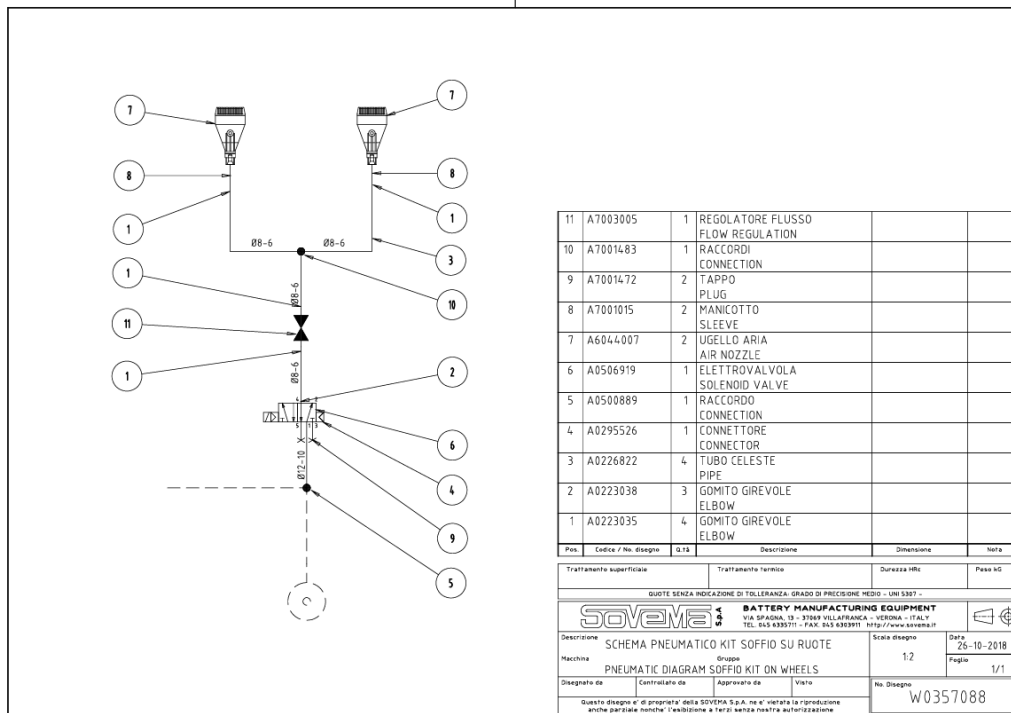
Technical Manager – Des Williams

Sovema Commissioning Engineer – Michelle Dorigotti

10 – Appendix

10.1 – Data and Information used within Project

The appendix of this report provides the end user with the full scale images and data that has been used throughout the report, these can be used to for a clearer interpretation when reading the report.



Reference to Section 5.3 – Pneumatic Diagrams

		Task Description	Isolation Procedure	Author:	Owen Williams	Issue Date:	Click to add text
		Plant Procedure No:	Click to add text	Approved By:	Click to add text	Revision No:	SEE FOOTER
		Plant Location:	Oxide Mill 3 & 4	Area Owner:	Click to add text	Review Date:	Click to add text
		Responsible Person:	Authorised Personnel	Frequency of check:	Click to add text	Compliance assured:	Click to add text
Step:	Major Step	Key Point Reason: Safety Quality Environment		Key Safety Criteria		Visual Aids / Supporting Images	
3	Ingot Cube Cut Process (x2 CU30/CU31).	1	When working on the Cube Cut Process isolate the Hydraulic System using the Control Cabinet Main Isolator (CU30/CU31).				
		2	Isolate the Pneumatic System using the local Air Supply Isolator (CU30/CU31).				
4	Nugget Forming System (Rollers). (x2 CU30/CU31)	1	When working on the Nugget Forming Process isolate the process using the Control Cabinet Main Isolator (CU30/CU31).		Note: Main Isolation Point MUST BE USED.		
		2			Inform Mill Operator of presence when working in the area.		
5	Nugget Outfeed Conveyor/Nugget Outfeed Conveyor (inclined) to Elevators/Transfer Conveyor.	1	When working on the Nugget Outfeed Conveyors isolate using the Control Cabinet Main Isolator (CU30/CU31).				
		2	Isolate the air supply to the Nugget Diverter Valve				
6	Nugget Elevators X2 (Mill 3&4) from CU30 and CU31).	1	When working on the Nugget Transfer Conveyors isolate using the Transfer System Control Cabinet Main Isolator.		Main Isolation Point MUST BE Used prior to accessing Elevator Inspection Hatch.		
		2	If Main Isolation is not possible Remove the Power Source (Local Plug) and Lock Out/Tag Out.				
Standard PPE		Chemical Hazards		Non Standard PPE			
							

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Step:	Major Step	Key Point Reason: Safety Quality Environment		Key Safety Criteria		Visual Aids / Supporting Images	
7	Nugget Transfer Conveyors to Silo's 1&2 (x3). Nugget Elevator to Silo's 1&2.	1	When working on the Transfer Conveyors isolate using the Main Transfer System Control Cabinet.	Note: Main Isolation Point MUST BE Used prior to accessing Elevator Inspection Hatch.			
		2	When working on the Nugget Elevator isolate using the Transfer System Control Cabinet Main Isolator.				
8	Lead Nugget Conveyor to Silo's 3 & 4.	1	When working on this conveyor the Main Control Panel and the Local Isolator Must be isolated and locked off.	Note: If using Local isolation only: Prior to working on the Nugget Conveyor – isolate the Nugget Elevators.			
		2	If it is not possible to isolate the Main Control Panel, the Local Isolator must be locked off as a minimum.				
9	Lead Nugget Storage Silo and Automated Control Feed to Mill (Vibrator System).	1	When working on this apparatus the Main Control Panel and Local Isolators for the vibrating motor must be locked off.	Note: Mill 4 feed does not have local isolation Point. Isolate using the Mill Isolator.			
		2	If it is not possible to isolate the Main Control Panel the Local Isolators must be locked off as a minimum.				

Reference to Section 5.5 – Standard Operating Procedure

Carrying Out General Maintenance activity on the Cube Cut Process.	Being struck by Elements which exist in the area (e.g. Ingots/Crane Jib)	Maintenance Operator	Only fully trained operators to operate the crane. Maintenance Operator to communicate with Mill Operator of presence in the area. Crane has 3rd party servicing.	4	2	8	Tolerable Risk	No Recommendations/Actions
Carrying Out General Maintenance activity on the Cube Cut Process.	Stored Energy	Maintenance Operator	Isolation Procedure and LOTO Procedure in place.	4	2	8	Tolerable Risk	No Recommendations/Actions
Carrying Out General Maintenance activity on the Nugget Transfer Conveyors to Elevator.	Slips, Trips & Falls	Maintenance Operator	Appropriate PPE, Ongoing Housekeeping Activities, through the TPM programme & floor demarcation. Hand Rails. Suitable Lighting. Dynamic Risk Assessment to be completed if conditions vary from the standard.	3	3	9	Tolerable Risk	Damaged and uneven floors to be repaired and coated. Steps and Walking Gantry's to be installed.
Carrying Out General Maintenance activity on the Nugget Transfer Conveyors to Elevator.	Stored Energy	Maintenance Operator	Isolation Procedure and LOTO Procedure in place.	4	2	8	Tolerable Risk	No Recommendations/Actions
Carrying Out General Maintenance activity on the Nugget Transfer Conveyors to Elevator.	Entanglement in Machine Moving Elements	Maintenance Operator	Electrical Isolation procedure in place (LOTO). Main Isolation to be used. All access gates/doors are fitted with Interlocks. Conveyor Guarding in Place.	4	2	8	Tolerable Risk	No Recommendations/Actions

Reference to Section 5.5 – Risk Assessments of Cold Cube