Die Extruder Modifications

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Bachelor of Science

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by

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ABSTRACT

This project focuses on modifying four existing plastic extrusion machines to meet modern industry and safety standards for a Fortune 500 company specializing in plastic packaging. The current machines lack critical safety features, such as emergency stops, secure wire management, and clearly labeled connections issues that pose significant risks to both operators and system reliability. The proposed solution includes the design and installation of custom operator stations with ESTOP functionality, quick-connect plugs for thermocouples and motors, and an in-house wire management system to prevent cable damage and misconnection. Research into the state of the art revealed a lack of innovation in extrusion equipment, highlighting the opportunity for safety and usability improvements. Engineering design considerations prioritized safe power connections, durable materials, and user-friendly operation, supported by customer feedback and finite element analysis for material selection. The project was completed ahead of schedule and under budget, offering a cost-effective and sustainable upgrade path for the client's manufacturing systems while significantly improving operator safety and operational efficiency.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

This project is to modify an existing extrusion machine to fit company and current industry standards for safety and machine operation. The project's scope is to design, engineer, build and install all modifications to the four existing extrusion machines on site. This includes a custom standalone operator station with estop, quick connect plugs for motor and thermocouple power, and an in-house designed mounted wire management system for wiring between the machine and operator stand.

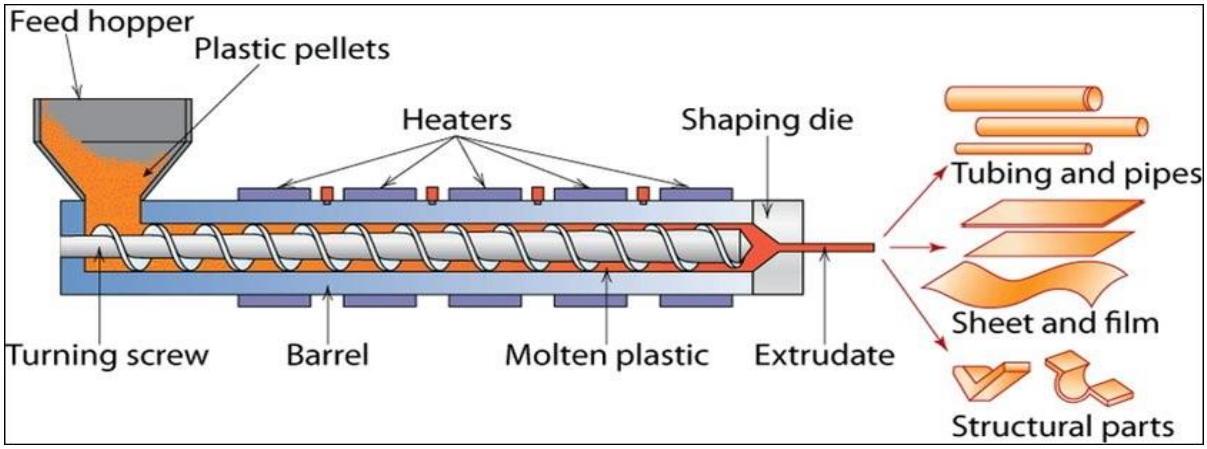
BACKGROUND AND SCOPE

This project came about when a fortune 500 company came to us with a simple issue, their machines lack critical components to be called safe and efficient. This company is a global leader in manufacturing plastic packaging which supplies retail stores all over the world, like Costco, with many of their plastic retail products. The issued lied in their several die extruder machines and their lack of operator and overall safety. The issue with the machines are that there is no safety in place for the operator to easily access in an emergency. Another issue is that when the die moves to and from the extruder, it is running over and crushing the motor, thermocouple, and feedback wires being run to it which is a major issue for the system control. Lastly, as all the current plugs look identical to each other, operators are mistakenly plugging in the wrong motors and getting the wrong feedback, which is a major issue for the system. We at APEC Engineering were commissioned to find a solution to their requests in a timely and cost-efficient way.

RESEARCH

CURRENT STATE OF THE ART

Plastic Extrusion machines were first invented in the 1790's and refined to the machines we know today where plastic was fed into a hopper, heated to melting temperature, fed through a shaping die and extruded to different shapes for manufacturing.



Plastic Extrusion Machine (3)

At this point in time there are only a few companies making these extrusion machines unless a private firm is hired to manufacture one. Throughout the history of the extruder, no major engineering innovations have been made that would make older models obsolete or less than another. With that said, safety upgrades were also not considered as each machine is used for a specific application and safety standards have drastically changed since the machine was installed. As this machine is so limited in its application, there is no standard for innovative technology besides standards set by the state that all must follow.

While this is not a vast market, there are still those who will innovate and push the limits of any machine and Diamond America is one of them. This company offers a custom extruder which effectively gives higher production, longer life, and a more consistent quality than its competitors. Another major innovation is the number of materials that their machines

can handle. This includes standard materials like silicone, rubber and plastic to more specialized materials like catalyst, ceramics and feedstock. The company offers all parts of the extrusion process from the actual extruder to the dies, feeders, mixers, cutter and controls as well as excellent customer services for any customer needs. In other words, a one stop shop for your extruder is needed when a high quality or even customer piece is needed (5).

On the other end of the spectrum are companies who do not innovate but just refurbish and resell used machines. This is a good option for a lot of companies as there may does not need the specialty of custom equipment, and they don't like the price tag that comes along with them. Arlington Machinery is a fitting example of a company rebuilding and resells are varieties of used machinery for much less than new custom machinery (6). While the downside to buying used is you may not find exactly what you're searching for, this option usually will get you what is needed without breaking the bank.

END USER

The end user of this will be employees of the company who are trained to use these Extrusion machines. The end user will be be able to quickly and efficiently swap or remove power from thermocouples and motors while having an ESTOP available to them in case of an emergency. The requirements to operate this machine are made through the company, but one must be an able-bodied man or woman to operate the heavy machinery within the system. The end user must possess knowledge of the operation of the machine and how to properly do maintenance on it. The company will benefit from this project as employees will feel safer working on these machines, and they will be more efficient to operate, so product production can increase as well.

CONCLUSIONS AND SUMMARY OF RESEARCH

From my research, I have learned a lot about the history and design of plastic die extrusion systems. Since the year of its first creation, not much innovation has hit this machine which has left it wide open for companies to modify them as they see fit, even if that is not up to the standards required of them. This has led to a gap in the state of the art, especially when it comes to current safety standards, which caused dangerous conditions for the end users are they handle these machines every day. APEC Engineering plans to use those gaps, along with customer features and influence from safety standards, to offer and create a solution to overcome these obstacles and please the end users and increase the productivity of all the die extrusion machines.

QUALITY FUNCTION DEPLOYMENT

CUSTOMER FEATURES

The following is a list of customer features that are required by the customer for the project:

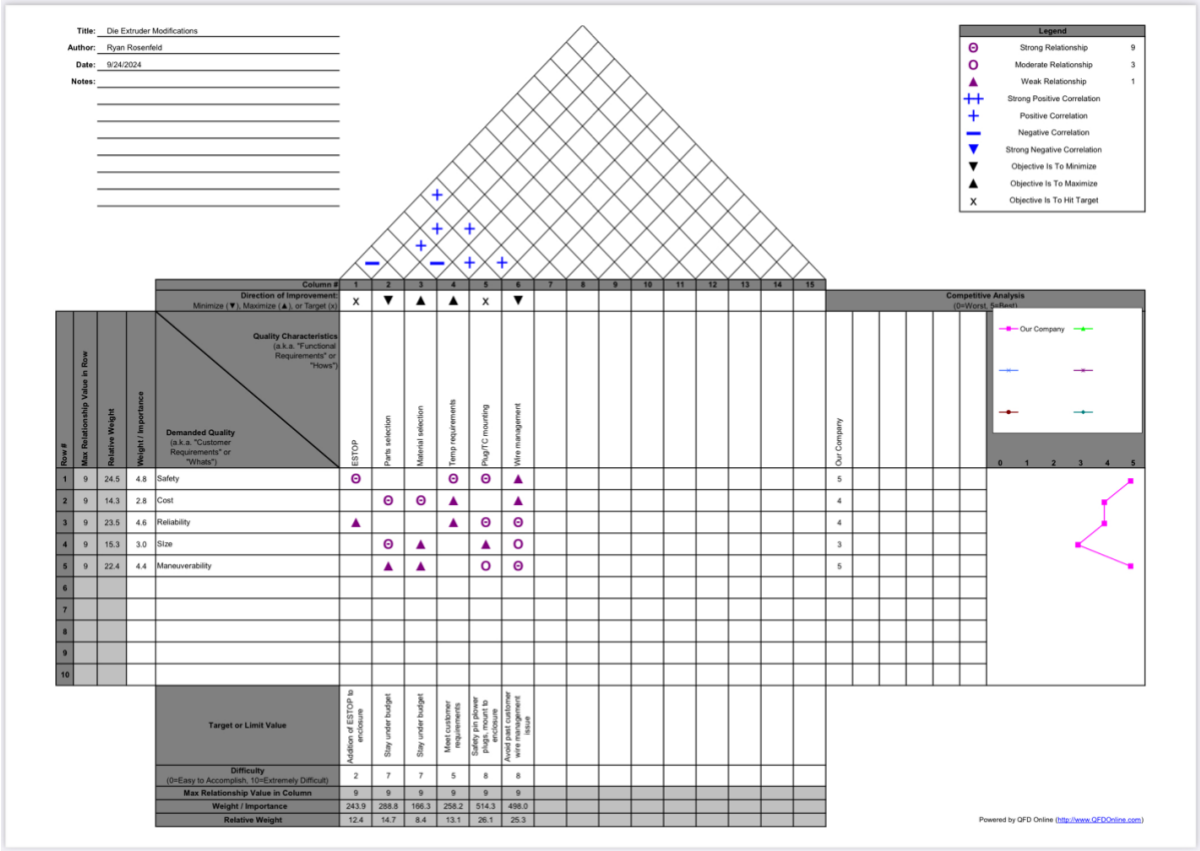
- Saginaw non-hazardous rated enclosures needed for machine
- System required to withstand maximum temperatures of 100 degrees F
- Must be robust to withstand a dirty harsh environment
- Cable looping from tap box to pedestal must not touch the ground
- ESTOP mounted to side of pedestal enclosure
- Thermocouple and power plugs mounted to back of pedestal enclosure

PRODUCT OBJECTIVES

Based on the House of Quality above, the following are the engineering characteristics in order of importance as well as a description each each characteristic for this project.

1. Power plug/Thermocouple mounting and wiring (26.1%)
    - Includes custom pinning for each plug for an individual fitment. As well as the importance of correct mounting placement on the enclosure for operator access.
2. Wire Management (25.3%)
    - Install Wire management clamp to machine as well as correct flexible metal conduit (FMC) to reduce wire movement and potential hazards.
3. Part Selection (14.7%)
    - Choose correctly rated parts for the area of the machine or per customer specification.
4. Temperature Requirements (13.1%)
    - Use fiberglass protected wire in excessive temperature areas.
5. Emergency Stop (12.4%)
    - Install emergency stop button in accessible area for operators.
6. Material Selection (8.4%)
    - Choose materials that will be acceptable for the environment but also cost effective for both company and customer.

House of Quality:



An over the phone survey was conducted between both APEC and Berry employees that are relevant to the project. This ended up being a survey of 5 people ranking the categories below 1-5. These are individuals who work in both the engineering and maintenance industries. The results of the surveys were used to create the table below.

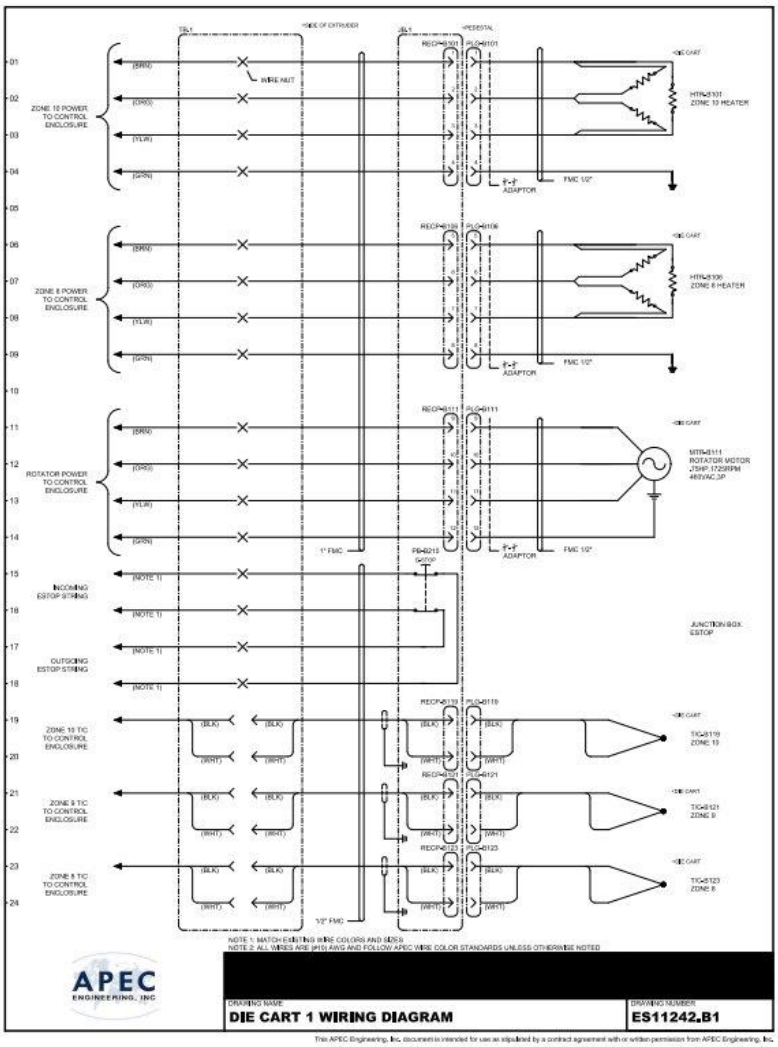
		Importance of the feature		Satisfaction with current technology	
Customer Feature	Total Surveyed	Average Rank	Standard Deviation	Average Rank	Standard Deviation
Safety	*5*	*4.8*	*0.45*	*2.6*	*0.54*
Cost	5	2.8	0.84	3.2	0.83
Reliability	5	4.6	0.55	4.0	1
Size	5	3.0	0.71	2.4	0.55
Maneuverability	5	4.4	0.55	1.6	0.55

Using our data found via our survey, we decided upon the engineering characteristics:

- Safety - Add ESTOP button to enclosure.
- Cost - Use standard industrial grade materials for more professional parts and installation.
- Reliability – upgrade existing FMC and replace power and T/C plugs with more robust models.
- Size – implement standing sized enclosure for easy reach but watch overall size as in tight space.
- Maneuverability – FMC must be flexible enough to move with the machine but not get caught in its tracks, Wire management system will be made to counter this issue.

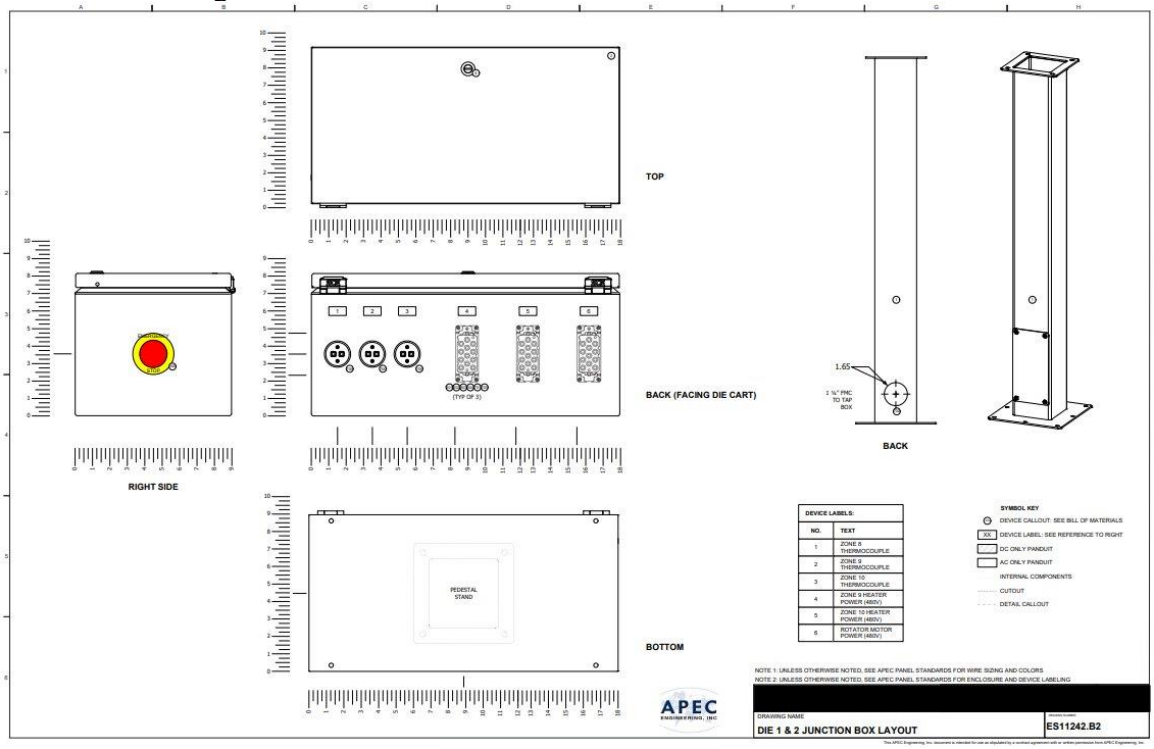
DESIGN

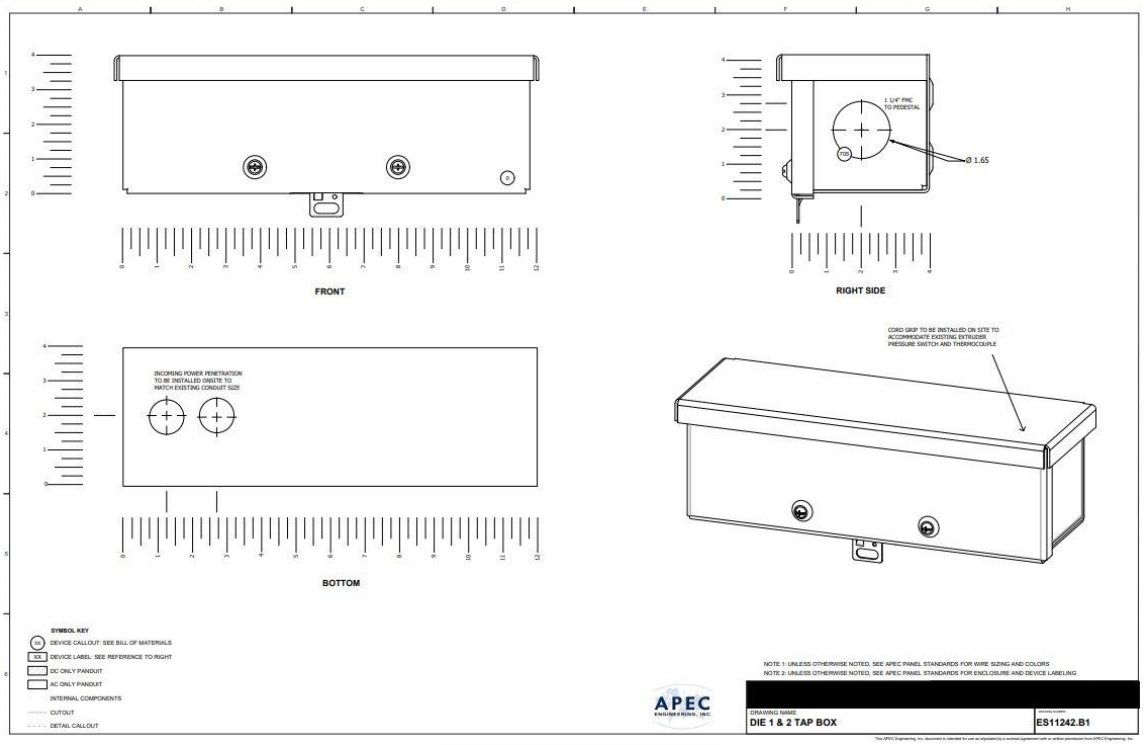
Electrical Schematics:

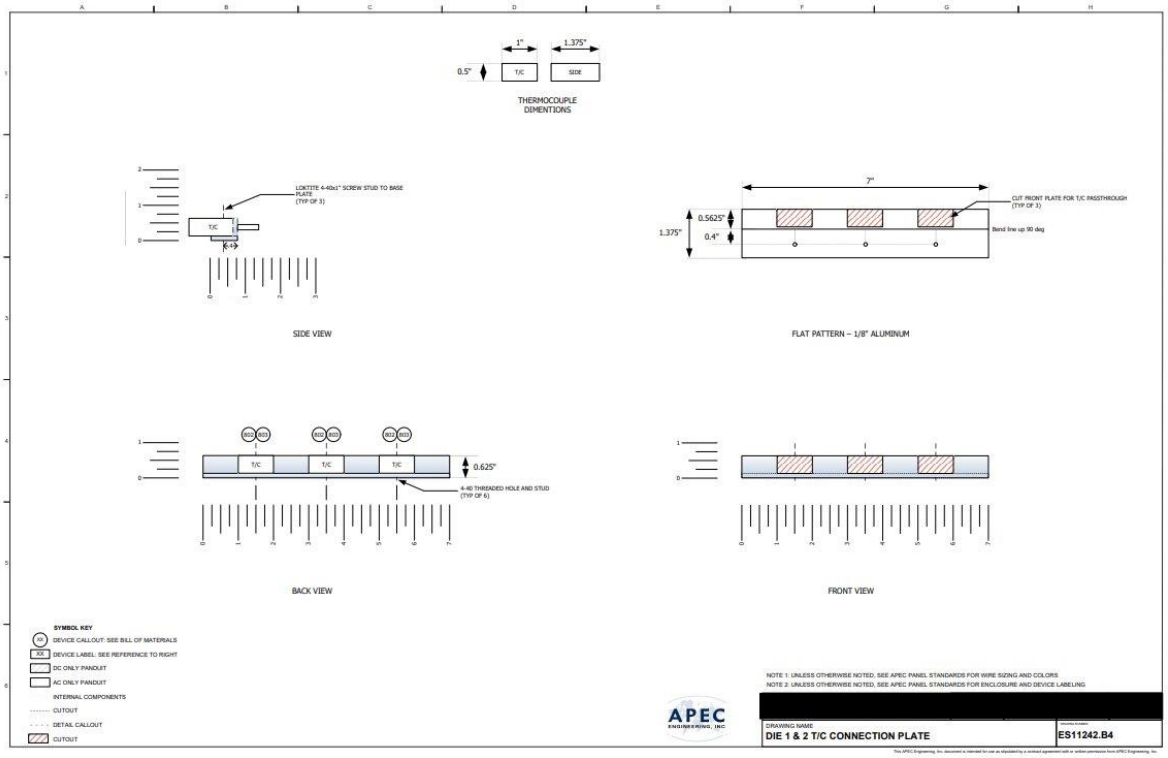


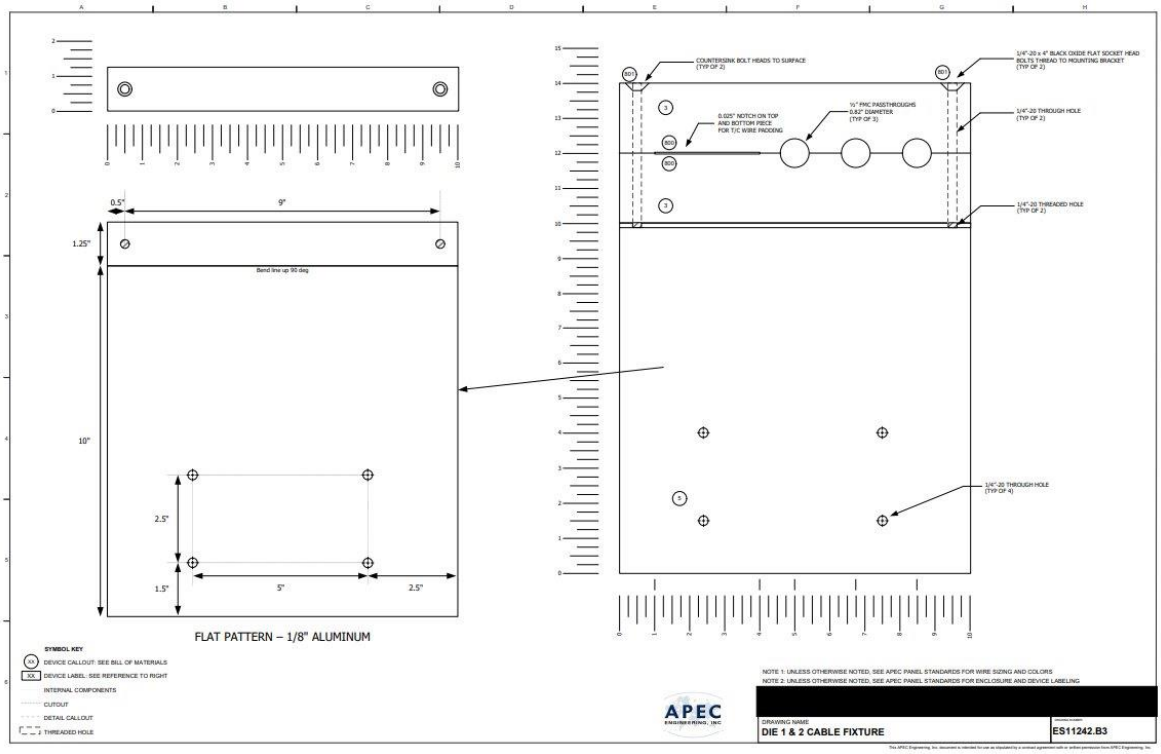
This document is meant to both be a schematic and interconnection diagram between the old and new system. This document shows the connection of extruder motors, thermocouples and Estop string.

Mechanical Design:





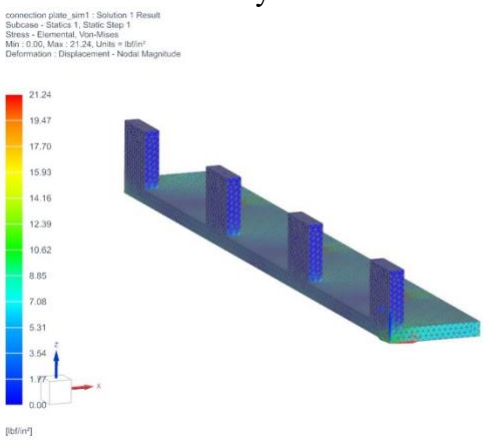




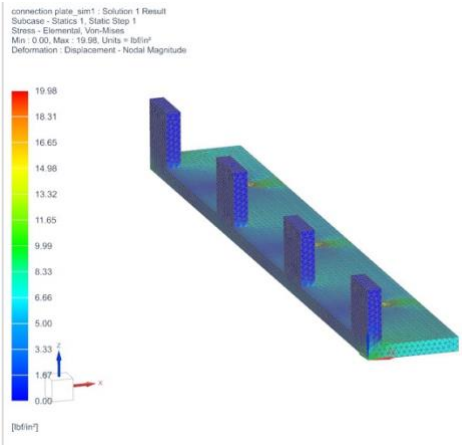
These four images make up the majority of the mechanical design for the project. The first image is the operator station where an ESTOP was mounted as well as all the connections to

the die cart. The second image is the tap box; this was used to internalize all the connections from the old system to the new one. The third image is thermocouple connection plate; the plate was designed under the idea of poka yoke. Operators were wrongly connecting the plugs and this helped eliminate that human error from the operation. The final image is the wire management system. This system eliminated the issue of high voltage wiring being crushed by the die cart. This originally caused many issues for both operator safety and machine efficiency. This solution effectively negated those in a simple and inexpensive way.

Finite Element Analysis:



(Aluminum 6061 FEA)



(Mild steel FEA)

A material stress analysis was done to determine the best material to make custom parts from. This was between Aluminum 6061 and mild Steel. The steel had less deformation but is less accessible and heavier material. Steel also corrodes over time where Aluminum does not. Conditions under normal human pull strength from an outlet of 10lbf (4.5N) in the horizontal direction. Other considerations are price of material and availability when choosing the material.

Bill of Materials:

Manufacturer	Part Number	Discription	QTY	UNITS	UNIT COST	EXTD COST
Automation direct	GCX1131	Emergency stop pushbutton, 22mm, twist-to-release, red	2	Each	$ 14.50	$ 29.00
Generic		Reducing Bushing, 1/2" to 3/4"	6	Each	$ 10.00	$ 60.00
Mitsubishi	Tivar 1000	1.75x2x10 blk UHMW-PE	8	Each	$ 25.00	$ 200.00
ProSense	THMJ-SPJ	Type J thermocouple connector, standard round pin panel jack, 400 deg F (200 deg C), glass filled thermoplastic body, black, thermocouple material pins, 32 AWG to 14 AWG wire size range.	6	Each	$ 10.00	$ 60.00
Mcmaster	75215K47	Weather-Resistant Enclosed Trough Raceway 12"x4"x4"	2	Each	$ 32.10	$ 64.20
Mcmaster	91253A566	Black-Oxide Alloy Steel Hex Drive Flat Head Screw,1/4"-20 Thread Size, 4" Long	8	Each	$ 1.38	$ 11.04
Mcmaster	93575A311	316 Stainless Steel Wing Nut, 4-40 Thread Size, pck of 10	2	Each	$ 4.07	$ 8.14
Mars Electric	STR12590	1-1/4 90 Degree Liquidtight Connector	2	Each	$ 29.22	$ 29.22
Mars Electric	STR125	1-1/4 Liquidtight Reusable Connector	2	Each	$ 16.51	$ 16.51
Mars Electric	6105-24-00	1 1/4IN Metallic Flexible Liquidtite Conduit, 50 ft Coil	1	50 ft Coil	$ 214.55	$ 214.55
Mars Electric	STR50	1/2 Liquidtight Reusable Connector	6	Each	$ 3.46	$ 3.46
Saginaw	SCE-44CCOL	Column, Straight, 35" H x 4" W x 4" D	1	Each	$ 161.25	$ 161.25
Saginaw	SCE-L9188ELJ	Trough Enclosure, 9" H x 18" W x 8" D	1	Each	$ 131.41	$ 131.41
Saginaw	SCE-MINQPL	Bracket, Mini Quarter Turn Padlock Bracket	1	Each	$ 7.48	$ 7.48
ILME	CPM-06	CP series, Male Rectangular Insert, size 77.27, 6 pin, 35 amp, Screw	6	Each	$ 25.04	$ 150.24
ILME	CHOT-16.4L	ILME CHOT-16.4L C-Type Metallic Hood, Size 77.27, 1/2" NPT, 2 Pegs	6	Each	$ 22.30	$ 133.80
ILME	CPF-06	CP series, Female Rectangular Insert, size 77.27, 6 pin, 35 amp, Screw	6	Each	$ 26.58	$ 159.48
ILME	CHI-16LS	Rectangular connector, Cover, Base,Bulkhead mount, size 77.27	6	Each	$ 36.38	$ 218.28
Mars Electric	STR12590	1-1/4 90 Degree Liquidtight Connector	1	Each	$ 29.22	$ 29.22
Mars Electric	STR125	1-1/4 Liquidtight Reusable Connector	1	Each	$ 16.51	$ 16.51
Mars Electric	STR50	1/2 Liquidtight Reusable Connector	5	Each	$ 3.46	$ 17.30
Saginaw	SCE-44CCOL	Column, Straight, 35" H x 4" W x 4" D	1	Each	$ 161.25	$ 161.25
Saginaw	SCE-L9188ELJ	Trough Enclosure, 9" H x 18" W x 8" D	1	Each	$ 131.41	$ 131.41
Saginaw	SCE-MINQPL	Bracket, Mini Quarter Turn Padlock Bracket	1	Each	$ 7.48	$ 7.48
Automation Direct	THMWJ-UL-16-1S-P-1	TE Wire & Cable Type J thermocouple PLTC extension wire, shielded, 2 conductors, 16 AWG, iron and copper-nickel, PVC conductor insulation material, white and red, PVC jacket, black, cut to length.	90	Each	$ 0.89	$ 80.10
ProSense	THMJ-SJ	Type J thermocouple connector, standard round pin jack, 400 deg F (200 deg C), glass filled thermoplastic body, black, thermocouple material pins, 32 AWG to 14 AWG wire size range.	6	Each	$ 5.25	$ 31.50
ProSense	THMJ-SP	Type J thermocouple connector, standard round pin plug, 400 deg F (200 deg C), glass filled thermoplastic body, black, thermocouple material pins, 32 AWG to 14 AWG wire size range.	6	Each	$ 4.00	$ 24.00
McMasterCarr	90368A102	Stainless Steel Knurled-Head Thumb Nut	12	Each	$ 3.88	$ 46.56
Mars Electric	STR50	1/2 Liquidtight Reusable Connector	6	Each	$ 3.73	$ 22.38
Norgren	820024-50KIT	Norgren mounting bracket, for use with Excelon 82 series components.	5	Each	$ 9.50	$ 47.50

ILME	CPM-06	CP series, Male Rectangular Insert, size 77.27, 6 pin, 35 amp, Screw	6	Each	$	20.14	$	120.84
ILME	CPF-06	CP series, Female Rectangular Insert, size 77.27, 6 pin, 35 amp, Screw	6	Each	$	21.59	$	129.54
ILME	CHOT-16.4L	ILME CHOT-16.4L C-Type Metallic Hood, Size 77.27, 1/2" NPT, 2 Pegs	6	Each	$	22.67	$	136.02
ILME	CHI-16LS	Rectangular connector, Cover, Base,Bulkhead mount, size 77.27	6	Each	$	36.38	$	218.28
Saginaw	SCE-44CCOL	Column, Straight, 35" H x 4" W x 4" D	2	Each	$	161.25	$	322.50
Saginaw	SCE-L9188ELJ	Trough Enclosure, 9" H x 18" W x 8" D	2	Each	$	131.41	$	262.82
Saginaw	SCE-MINQPL	Bracket, Mini Quarter Turn Padlock Bracket	2	Each	$	7.48	$	14.96
ProSense	THMJ-SJ	Type J thermocouple connector, standard round pin jack, 400 deg F (200 deg C), glass filled thermoplastic body, black, thermocouple material pins, 32 AWG to 14 AWG wire size range.	6	Each	$	5.25	$	31.50
ProSense	THMJ-SP	Type J thermocouple connector, standard round pin plug, 400 deg F (200 deg C), glass filled thermoplastic body, black, thermocouple material pins, 32 AWG to 14 AWG wire size range.	6	Each	$	4.00	$	24.00
ProSense	THMJ-SPJ	Type J thermocouple connector, standard round pin panel jack, 400 deg F (200 deg C), glass filled thermoplastic body, black, thermocouple material pins, 32 AWG to 14 AWG wire size range.	6	Each	$	10.00	$	60.00
McMaster	75215K56	Weather-Resistant Enclosed Trough Raceway with Bonding and Grounding Studs, 6" Wide x 6" Deep, 1-1/2 Feet Long	1	Each	$	78.98	$	78.98
Mars Electric	STR12590	1-1/4 90 Degree Liquidtight Connector	2	Each	$	28.40	$	56.80
Mars Electric	STR125	1-1/4 Liquidtight Reusable Connector	2	Each	$	16.05	$	32.10
Automation Direct	THMWJ-UL-16-1S-P-1	TE Wire & Cable Type J thermocouple PLTC extension wire, shielded, 2 conductors, 16 AWG, iron and copper-nickel, PVC conductor insulation material, white and red, PVC jacket, black, cut to length.	90	Each	$	0.89	$	80.10
Automation Direct	THMWJ-UL-16-1S-P-1	TE Wire & Cable Type J thermocouple PLTC extension wire, shielded, 2 conductors, 16 AWG, iron and copper-nickel, PVC conductor insulation material, white and red, PVC jacket, black, cut to length.	90	Feet	$	0.89	$	80.10
					Cost:		$	3,841.71
					Total cost: (4 machines)		$	15,366.84

This bill of material shows the cost breakdown of all materials used for the project as well as the total material cost for four machine modifications.

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Cost per unit:	$3,841.71
Total cost (4 machines):	$15,366.84

Customer quote: $60,000

Target budget = (60,000)/2 – (~15000) = $15,000 for assembly and installation for all four units. This leaves for a target 50% profit margin on this job.

SCHEDULE, PROPOSED /ACTUAL

Milestone	**Estimated Dates**	**Actual Dates**
Electrical Schematics Complete	Dec 30, 2024	Nov 22, 2024
Electrical Enclosure Layout Complete	Jan 15, 2025	Nov 22, 2024
Mechanical Design Complete	Jan 31, 2025	Nov 22, 2024
Materials Ordered	Feb 3, 2025	Jan 1, 2025
Materials arrive/Assembly Start	Mar 3, 2025	Feb 17, 2025
Finish Assembly	Mar 31, 2025	Mar 5, 2025
Installation and Startup	April 1, 2025	Mar 28, 2025

SUSTAINABILITY AND MATERIAL USAGE

The improvement that I believe would have been extremely beneficial would have been to find a more standardized off-the-shelf product when it came to the wire management solution. The use of a flexible cable tray system would eliminate those concerns while offering an arguably better solution. The system would remove excess tension placed on the wires and debris would not collect on the system like it can now. Another flaw of the current solution is its material; the custom system is made mostly of plastic which can crack or deteriorate over time where the flexible tray is made of aluminum and does not have those drawbacks. In conclusion, the use of a flexible cable tray system is a lot more sustainable and reduces the material usage in the long term for this machine.

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