ASSEMBLY & MATERIALS

ME30356 Reverse Engineering
Callum Morrison
VAX UCPESHV1

PRODUCT STRUCTURE

257	167	97	15	8	11
COMPONENTS	UNIQUE ITEMS	FASTENERS	FASTENER TYPES	PLASTIC TYPES	ELECTRONIC PARTS*

SCREWS are used throughout. All are **standard Phillips head**. The vast majority are one type; self tapping 3x15, allowing for bulk purchasing which reduces costs. **Self tapping screws** also simplify manufacture; no tapping.

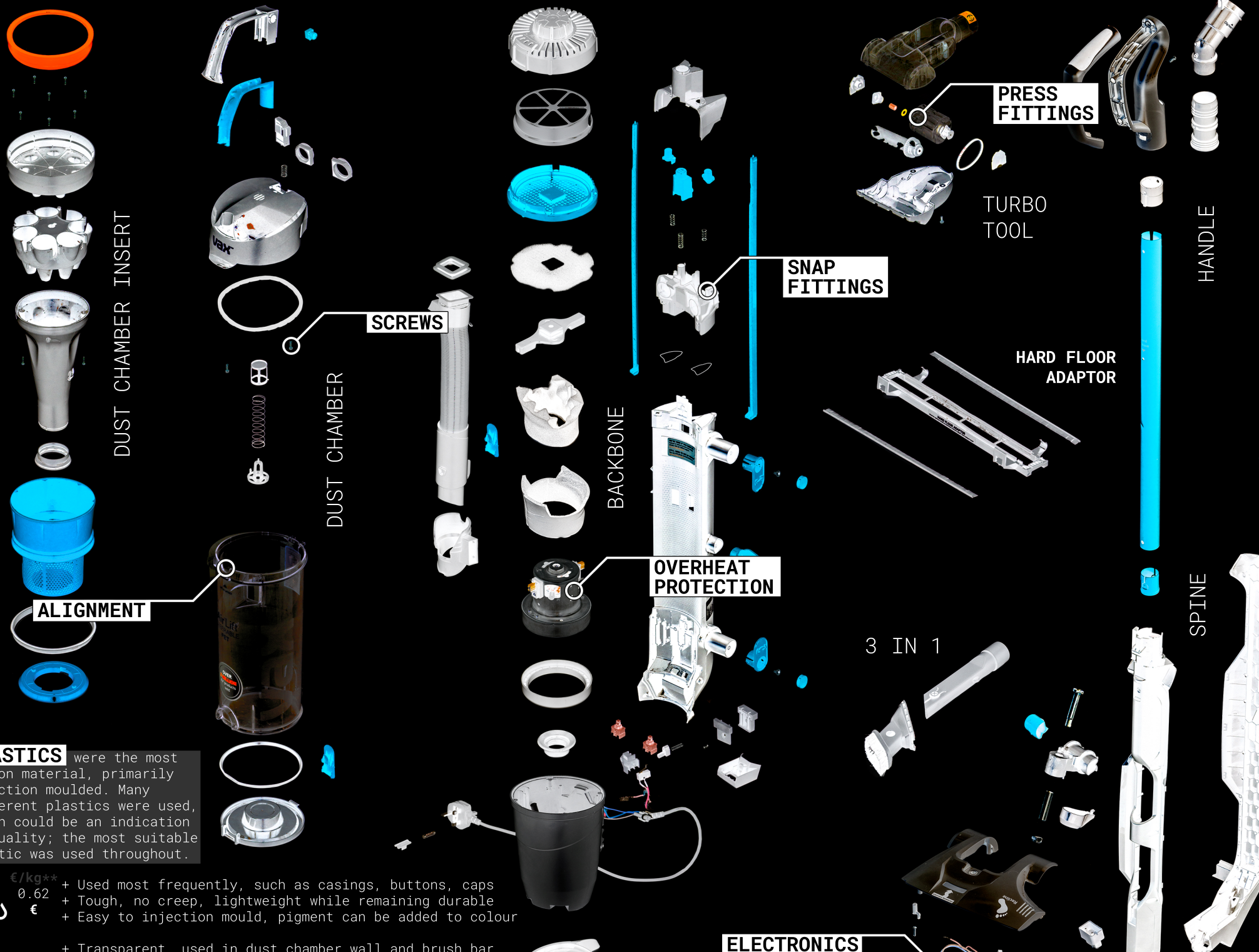
SNAP FITTINGS enable assembly without tools, or additional materials such as glue or fixings. Designed into the injection moulded part, **cantilever fittings** are used frequently, notably on the head of the spine which is not intended to be disassembled. Additional cost is from added mould complexity.

PRESS FITTINGS are used less frequently, despite not requiring complicated geometry like snap fittings. This may be due to increased tolerance or equipment requirements, increasing cost. **No plastic-plastic press fittings** were observed. The most notable press fitting was for the turbo tool rotor.

ALIGNMENT of assembled parts may be vital, for example the inner chamber has **clocked holes** to promote a cyclone. To ensure part is assembled correctly, a cut-out on the outer wall receives a protrusion on the chamber; it only fits in one orientation. Parts **not intended for user interaction** may not use alignment mechanisms as workers / machines can be taught to assemble correctly.

ELECTRONICS are reasonably sparse throughout. The universal motor / turbine is built into a **pre-supplied component**. All electronics are grouped into either the lower backbone, or the brushbar - meaning subsystems requiring electronics could be **handled in isolation** by a different department.

OVERHEAT PROTECTION is built into the the **motor assembly**. A PTC thermistor in series with the motor limits current to the motor as it heats up.



PLASTICS were the most common material, primarily injection moulded. Many different plastics were used, which could be an indication of quality; the most suitable plastic was used throughout.

	€/kg**	
ABS	0.62 €	+ Used most frequently, such as casings, buttons, caps + Tough, no creep, lightweight while remaining durable + Easy to injection mould, pigment can be added to colour
PC	1.00 €€€	+ Transparent, used in dust chamber wall and brush bar + Tough, durable, available in many different grades - Limited scratch resistance, may yellow over time
PP	0.56 €	+ Semi-rigid; prevents cable hook breaking upon use + Easy to injection mould, non toxic - Not as tough as ABS, won't withstand as much abuse
TPE	0.61 €	+ Exhibits advantages of combined rubbery and plastic materials + Soft grip for handles, while remaining durable + Over-moulded onto ABS for endurance and assembly ease; no glue
PA	0.84 €€	+ Nylon bristles on brush bar and turbo tool, some housings + Highly flexible to allow 'sweeping' motion of bristles + Tufting process allows fast, automated assembly of parts

ASSEMBLY of the product was likely done with substantial human input (made in China where labour costs are traditionally low), and in some form of hybrid assembly line (large sales figures, subsystems likely shared across Vax range). Semi-specialised tools likely assist, but bespoke robots may be too expensive.

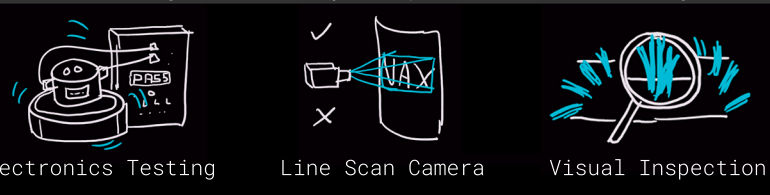
Assembly Line
Based on the quantity of product manufactured (2m Air products), and the country of assembly (China) it is likely that a **single, fixed fitter, assembly line** is used with **primarily manual workers**, however automated cells could be used for some operations such as press-fitting turbo tool shaft.

Automation
Hard automation is likely used for **highly common parts** between product (e.g. tufting brush bar), however due to cost soft automation may not be.

Tools
Tools are likely used to assist manual workers, based on research of existing assembly lines. Tools could include **electric screwdrivers** which hold the screw, and torque to set levels.

OUTSOURCE.
Vax do not own a factory in China where the product is made. Is is likely that assembly of the product is **outsourced to an external supplier(s)**. This may have an effect on quality, and will likely reduce assembly costs when compared to assembly in Europe. This increases the likelihood of manual labour assembly.

QUALITY CONTROL. As Vax are perceived as a 'high quality' brand, it is highly likely that QC checks are performed throughout assembly to uphold their brand image.



APPENDIX.

* as likely received at the assembly line - e.g. pre-assembled PCBs are 1 part.
** prices from plasticker.de

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DEEP DIVE

UPPER SPINE CAP

Material: ABS | **Assembly:** SNAP FIT & SCREWS | **Finish:** PAINTED

- Manually pressed onto lower spine cap, **cantilever snap fit** in place. Difficult to remove without damage. Very secure.
- Screwed onto spine to ensure detachment is impossible.
- Aesthetically pleasing finish, and secures buttons underneath.
- Painted on outer surfaces with **gloss black speckled paint**.

POST-MOTOR FILTER & CAP

Material: ABS & PAPER | **Assembly:** TWIST LOCK | **Clocked:** YES

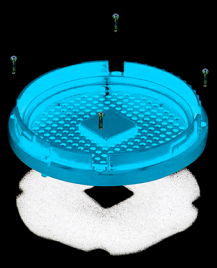
- Filter must be **replaceable** when 'discoloured'. Manual states filter damaged if 'washed or scrubbed'.
- Pre-motor filter can be cleaned, but this filter is made from rows of paper, required for **finer filtration**.
- Assembly in factory will be same process as a user after replacing the filter with a new part. **No tools required**.
- ABS is **tough** to allow for thin slots on top of cap; needed to allow airflow through filter.
- Filter also used in 15 other VAX models; large stock.

LOWER SPINE CAP & BUTTONS

Material: ABS | **Assembly:** SNAP FIT | **Finish:** A1, PIGMENT

- Protrusions spigot base of button springs. Buttons slide into groove in cap, and **cantilever latch** prevents detachment.
- Could be assembled by automated machine, however manual workers are likely cheaper and **fast enough** to withstand demand.
- Base of buttons take radial latch in pusher rod, ensuring rod comes up with button spring (switch on end would also help).
- Pressing assembly down onto spine & rods will latch them correctly; the **extra alignment step above is not necessary**.
- Blue pigment ABS (possibly Phthalocyanine) used to create button colour (matching with rest of product **colour theme**).
- A1 finish indicates extra glossy (low mould surface roughness of 0.012 to 0.025 Ra), however this seems **visually inaccurate**.

MOTOR CAP & FILTER



Material: ABS & PPI FOAM | **Assembly:** SCREWS | **Serviceable:** NO

- Motor cap secured with four **Phillips head** screws; enough to discourage further disassembly, however **not as safe** as star or other safety head screws. Likely cheaper as a result.
- Cap contains holes for airflow like post-motor filter cap, ABS is chosen for high toughness, **reducing risk of damage**.
- Filter is not intended for user replacement, and therefore very coarse to **minimise blockages** which reduce suction.

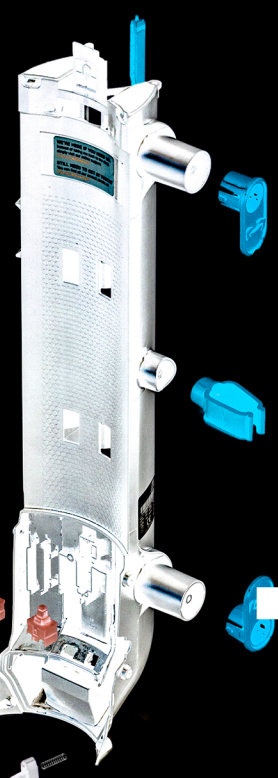
MOTOR BRIDGE & CLADDING

Material: NATURAL RUBBER & PU / PE FOAM | **Assembly:** LOOSE

- Moulded rubber bridge is **placed** on top of motor; grooves in motor and wall **secure orientation**. The part provides torsional support for motor, which is otherwise unsecured.
- **Polyurethane** 'acoustic' foam forms an inner layer of sound insulation; helping to minimise noise escaping the motor.
- **Polyethylene** outer layer may minimise water ingress (closed cell foam), and further reduce motor acoustic levels.

SPINE SUBASSEMBLY

Material: ABS | **Assembly:** VARIOUS | **Finish:** VARIOUS (A1 STATED)



- Large injection moulded part makes up main structure of lift out assembly. Due to moulding constraints, holes at the bottom must be filled. Separate panels are adhered in place using **plastic solvent**. Likely requires trained workers or automation.
- 3in1 tool clip, and cable hooks secured each with one screw. Parts are **self-aligning**, manual worker likely uses assembly line screwdriver to torque screws correctly and quickly.

Step 1
- Bend rod
- Slide from bottom

Step 2
- Rod to top
- Straight

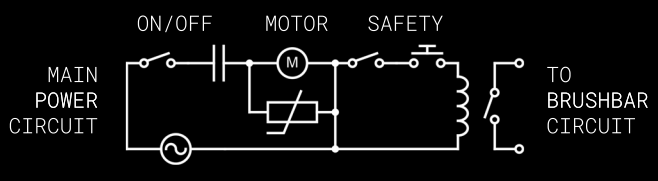
Step 3
- Insert switches & button

- Rods are prevented from sliding in straight; each one **must be bent** to insert. Robotic assembly would require precision tuning and complex programming; likely done by manual worker. PP could be suitable due to bending characteristics, however PC was used, possibly with an additive to improve flexibility.

MOTOR & ELECTRONICS

Assembly: LOOSE / SPADE TERMINALS

- Motor loose in housing; secured by rubber bridge and motor cap.
- No PCB or SMD electronics used here (used in brush bar). Assembly of electronics done entirely with spade connectors (for switches) and closed crimp connectors. Likely **crimped by hand**, using a manual tool.
- Most electronics can be pre-assembled; only switches need connecting during mating of motor housing and backbone. Limits worker exposure of electronics to **final assembler**.

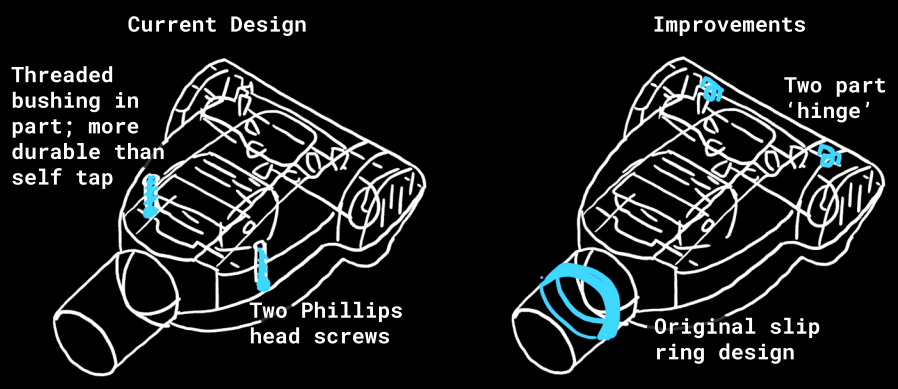


IMPROVEMENTS

TURBO TOOL.

A previous Vax design used a slip-ring to assemble the two halves together. The user could split the tool for cleaning and maintenance. Currently, two screws assemble the halves; meaning no user maintenance.

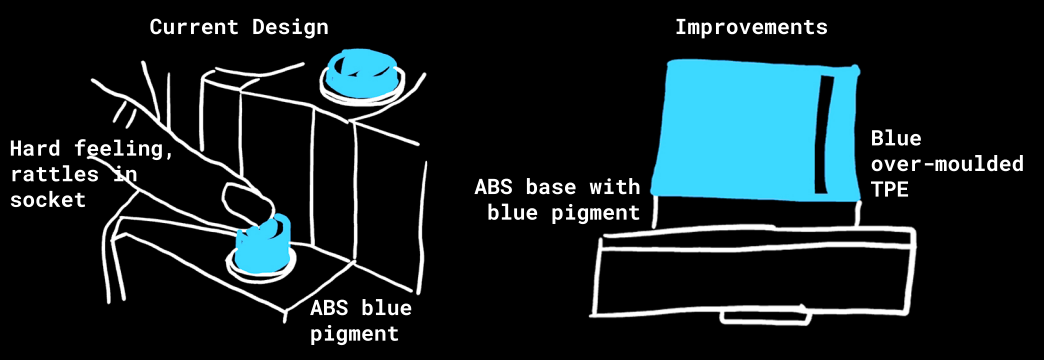
Highlighted issues:
1. Turbo tool cannot be disassembled without tools.
2. Part is a 'consumable' item - Vax encourage replacement not repair.



BUTTONS.

One of the issues that surfaced during functionality and user testing was the low-quality feel of the buttons. Made from ABS with blue pigment, the buttons are durable and stand out.

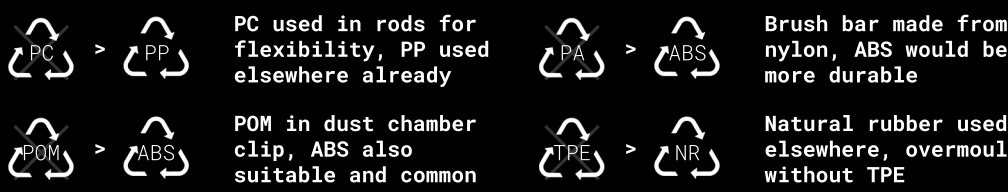
Highlighted issues:
1. Button feel is low quality.



PLASTICS.

There were (at least) 8 different types of plastics used throughout the product. Although some are required due to material properties, it is likely that the material requirement could be simplified.

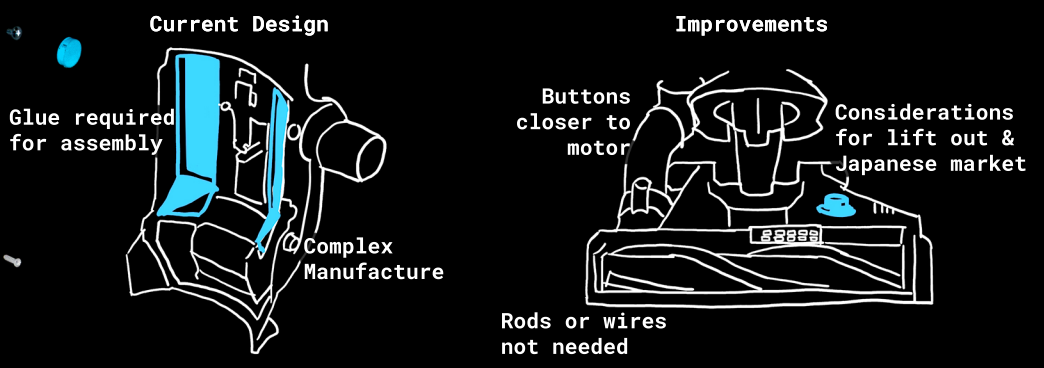
Highlighted issues:
1. Large variety of plastics required to produce product.



BACKBONE.

Assembly of backbone subassembly requires substantial bending of two rods, which are used to transmit button presses down to the switches mounted in the base near the motor. To accommodate the manufacture of this design, two panels must be glued using plastic solvent.

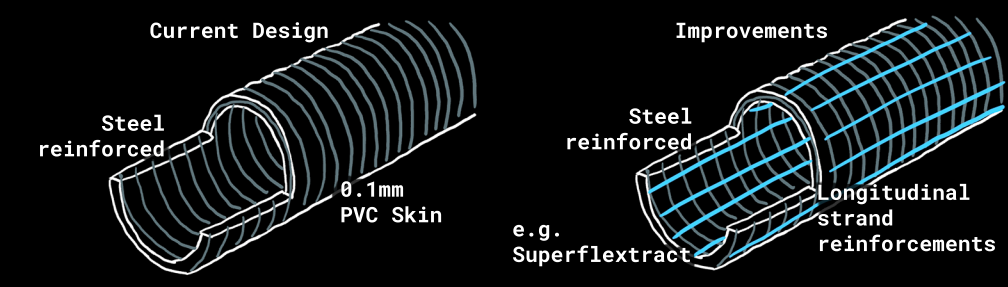
Highlighted issues:
1. Insertion of rods results in substantial plastic bending.
2. Plastic solvent needed to assemble (only occurrence in product).



HOSE.

The hoses are lightweight, made from helically wound steel wire, surrounded by a thin, clear, PVC (or TPU) skin. Upon disassembly, the skin would rip easily, especially with pinching or tugging (normal use wear).

Highlighted issues:
1. Vacuum hose is easy to pierce and tear.



SCREWS > SNAP FIT.

97 screws are used throughout the product. Although many are vital (e.g. preventing motor access), many could be replaced with snap fittings. The upper spine cap is held on with snap fittings and screws - yet during disassembly removal of screws did not appear to affect link strength.

Highlighted issues:
1. Screws may be used unnecessarily. Despite minimal material cost improvement, time taken to assemble is dramatically increased with screws not snap fits.