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STAP:- Applied to a Slurry Dispenser

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Background :-

- Contracted to fill several sizes of container with a curing slurry.
- Needed a rapid and accurate means of dispensing slurry into the container bodies.
- Filling trolley proposed which fitted under the mixing bowl and delivered a “dose” of uncured slurry into the container body using a volumetric pump.

- ……There were Issues!

Filling Issues

- Dispenser blocked when using a curing formulation.
- Overfills, under fills, and cavities when filling medium sized containers.
- “Safe” vacuum declared when no vacuum existed.
- No correlation between commissioning and first off production material trials.
- Control actions blamed!
- Could STAMP help analyse the situation and provide a solution?
- Current Process Control Plan (PCP) based on the “Process Trilogy”.
  - Process Flow
  - PFMEA
  - PCP
- Very detailed. Some 230 lines.

- Can we see the wood for the trees?

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The Design Book

- A Systems Engineering “Design Book” had been collated to look at the filling of Containers and followed the process map from the previous slides.
- What does the design book do?

  - Validates the function requirements deliver our customers requirements set.
  - Identifies the selected means of achieving the design functionality.
  - Identifies the key features within those selected means
  - Identifies the noises and controls within the design space
  - Expresses the means for reducing the noises and applying the controls.

- But we know from bitter experience how we make what we make is important too……

Design and Process Picture

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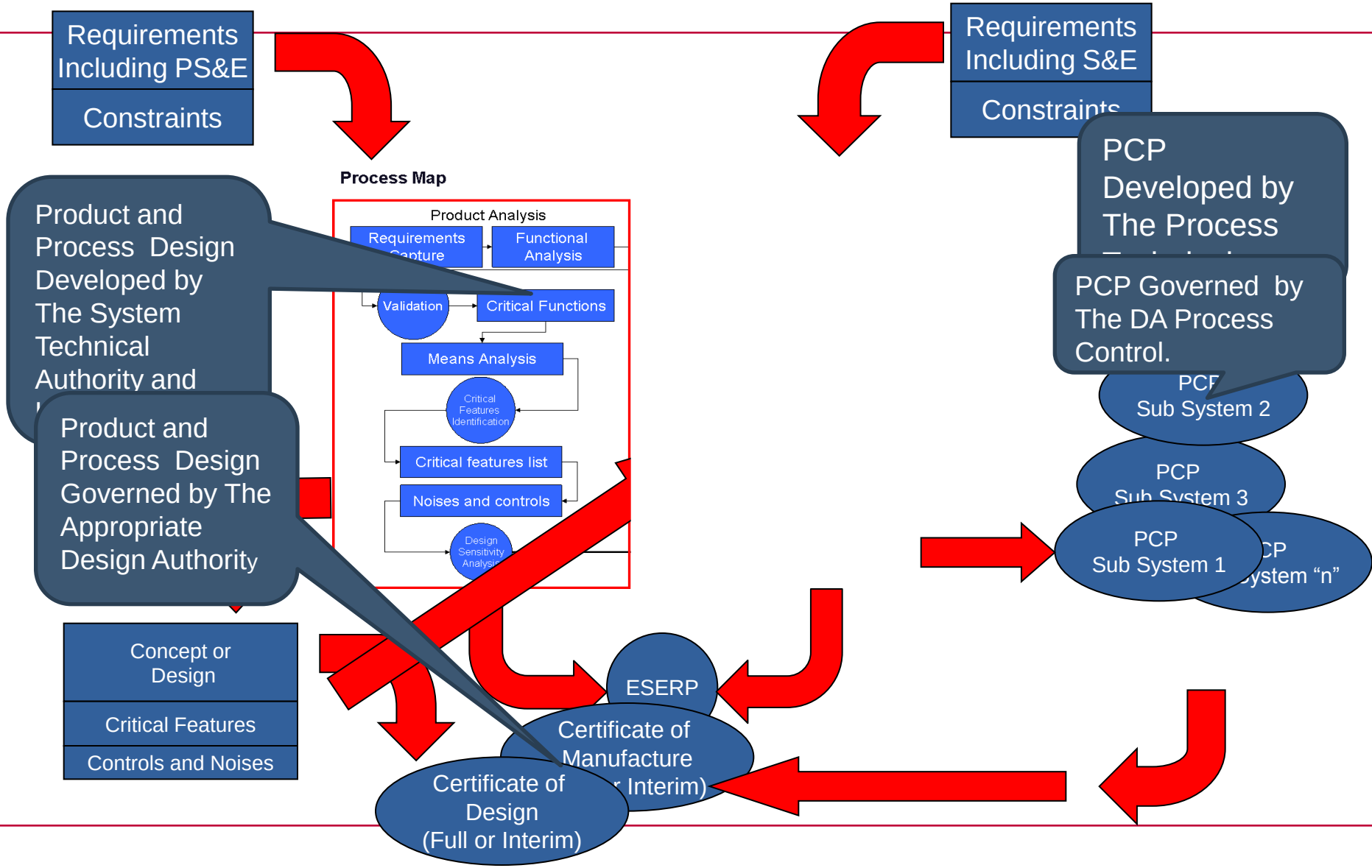
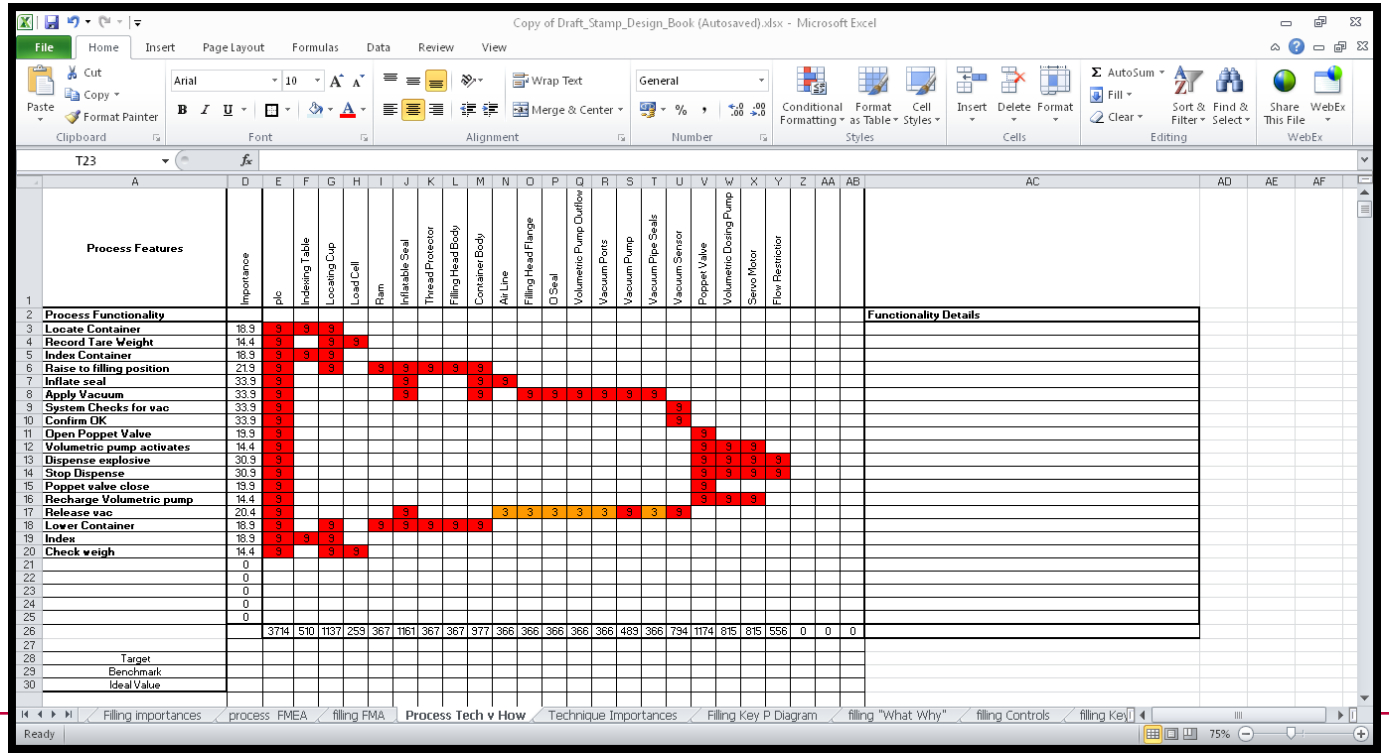


Computer Control…….Control taken for granted?

- Reaction of the team to questioning at review was “Don’t worry about that, it’s all computer controlled!”
- My questions were as follows :-
  - What are we controlling?
  - How are we controlling it?
  - What happens when the control actions go wrong?
  - Are we controlling the right things?
  - Is there anything missing?
- Where do we start?

Filling the Container

- Develop a process flow map for the filling process :- Describe as functions.
- Assign means of achieving those functions and explore the relationship between them.



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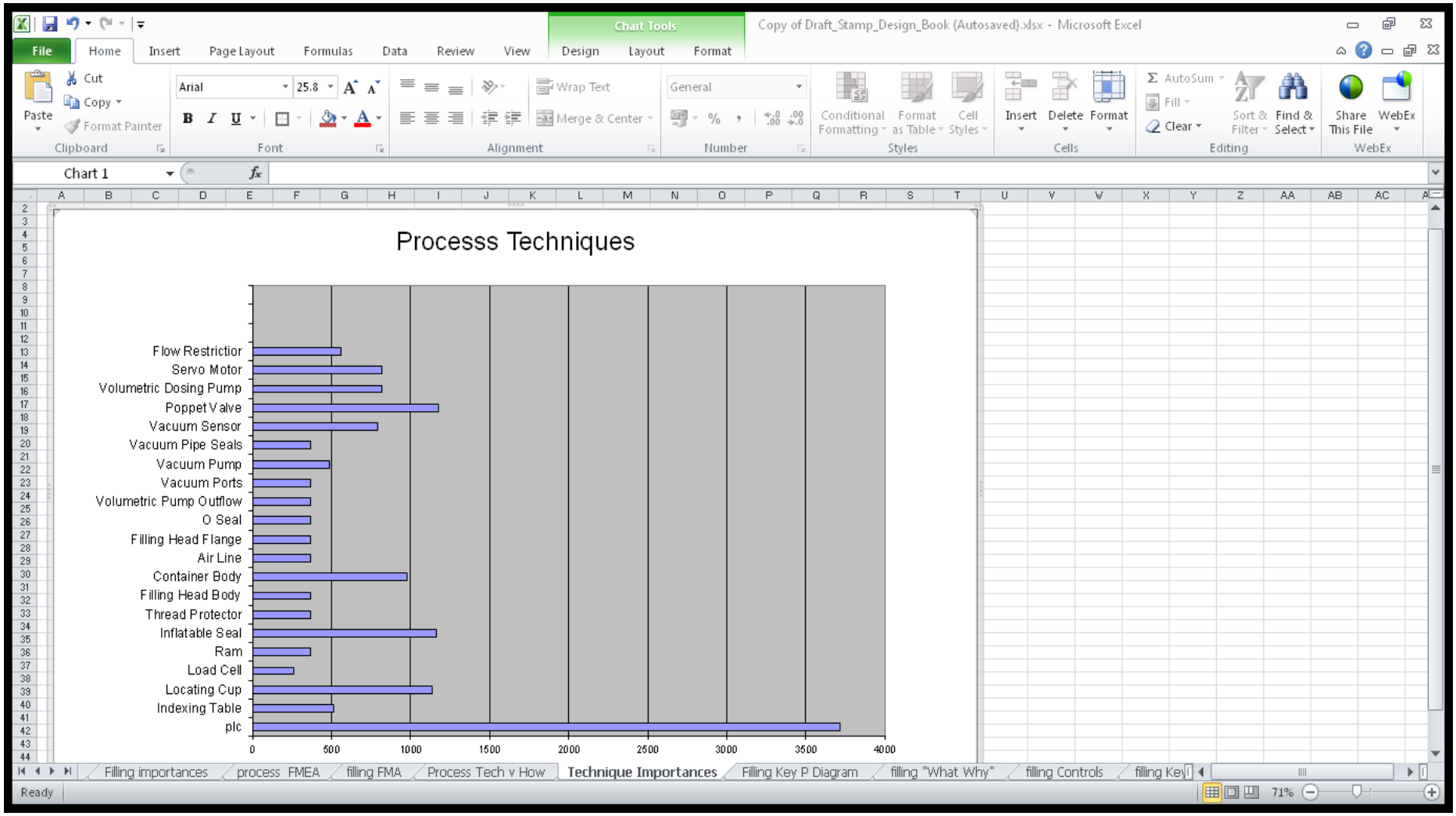
Assess Critical Functions



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Noises and controls.

- There are actions in our filling process which we need to control.
- There are also noises from the outside world which affect these control actions.
- We need to know where these noises impinge.
- Enter the what / why table.
- The first stage in it’s construction is the development of a parameter diagram. This defines the control space and lists the noises and controls.
- Noises are categorised as unit to unit, deterioration an external.

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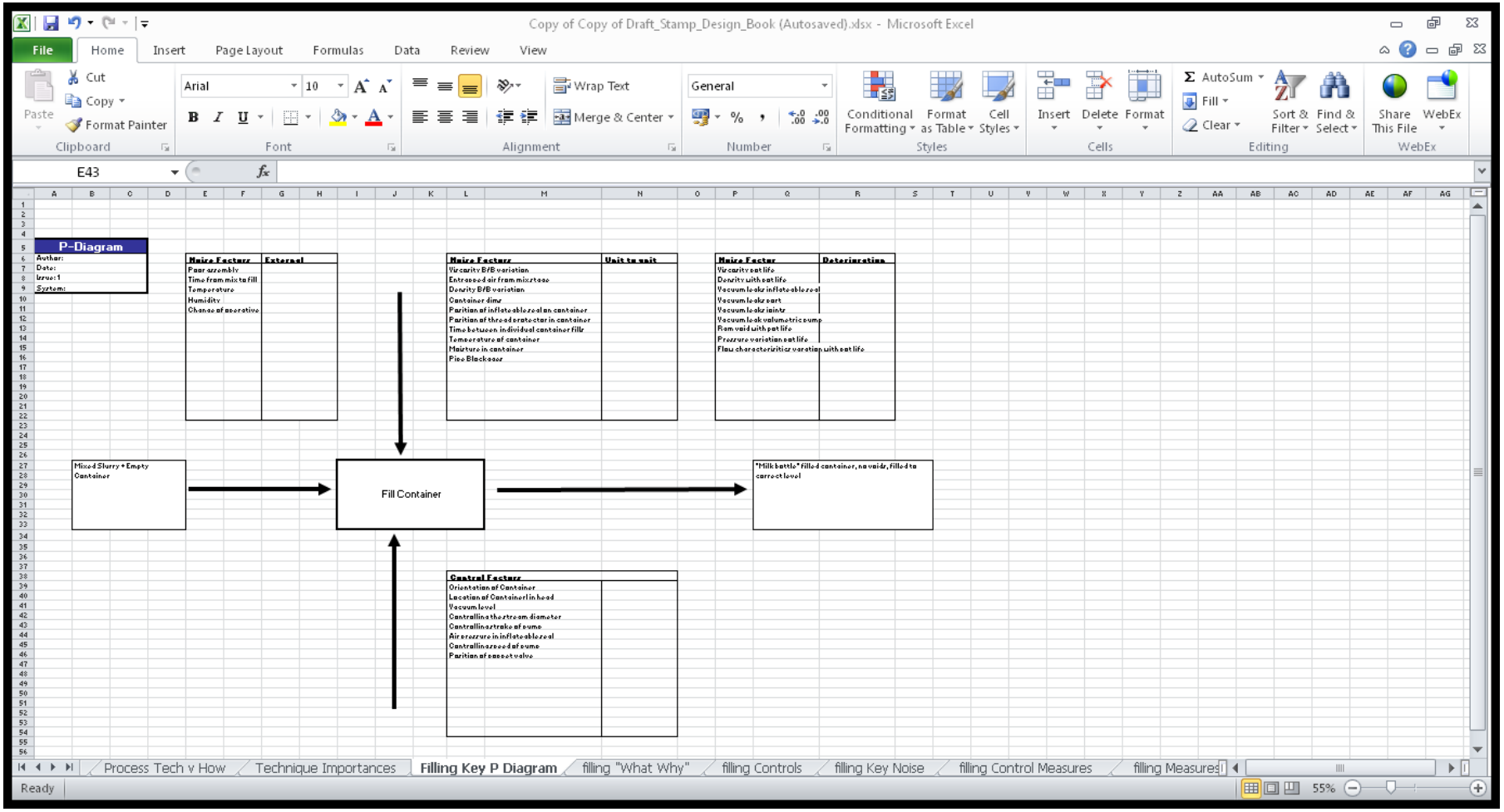
P-diagram



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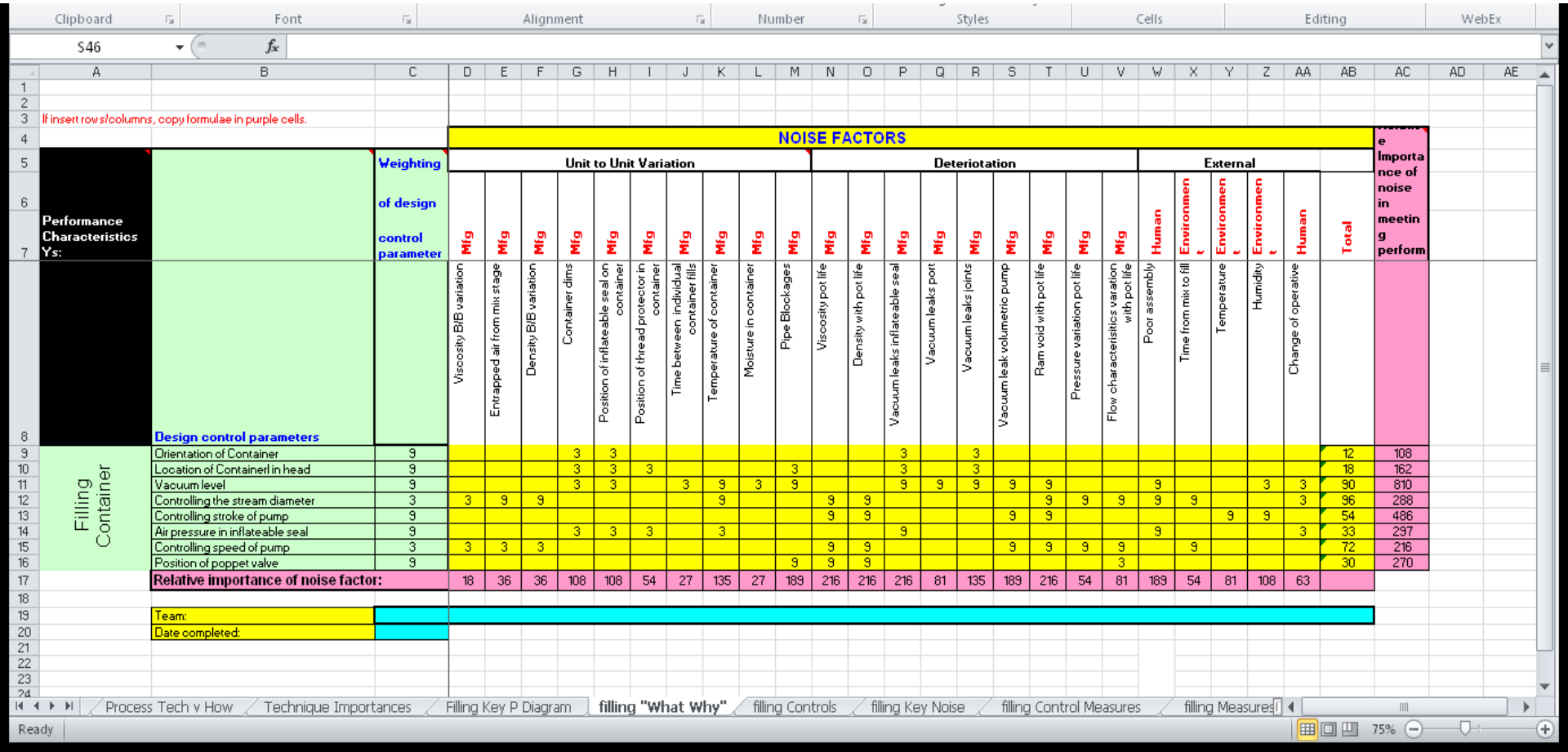
What why table.

- This is developed into the What Why table where the relationships between noises and controls are explored.



If insert rows/columns, copy formulae in purple cells.

			NOISE FACTORS																													
			Unit to Unit Variation										Deteriotation									External										
Performance Characteristics Ys:		Weighting of design control parameter	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Mfg	Human	Environment	Environment	Environment	Human	Total	Relative importance of noise in meeting performance
	Design control parameters		Viscosity B/B variation	Entrapped air from mix stage	Density B/B variation	Container dims	Position of inflateable seal on container	Position of thread protector in container	Time between individual container fills	Temperature of container	Moisture in container	Pipe Blockages	Viscosity pot life	Density with pot life	Vacuum leaks inflateable seal	Vacuum leaks port	Vacuum leaks joints	Vacuum leak volumetric pump	Ram void with pot life	Pressure variation pot life	Flow characteristics variation with pot life	Poor assembly	Time from mix to fill	Temperature	Humidity	Change of operative		
Filling Container	Orientation of Container	9				3	3								3			3									12	108
	Location of Containerl in head	9				3	3	3				3			3			3									18	162
	Vacuum level	9				3	3		3	9	3	9			9	9	9	9	9			9			3	3	90	810
	Controlling the stream diameter	3	3	9	9					9			9	9					9	9	9	9	9			3	96	288
	Controlling stroke of pump	9											9	9				9	9					9	9		54	486
	Air pressure in inflateable seal	9				3	3	3		3					9							9				3	33	297
	Controlling speed of pump	3	3	3	3								9	9				9	9	9	9		9				72	216
	Position of poppet valve	9										9	9	9							3						30	270
	Relative importance of noise factor:		18	36	36	108	108	54	27	135	27	189	216	216	216	81	135	189	216	54	81	189	54	81	108	63		

Team:	
Date completed:	

Process Tech v How | Technique Importances | Filling Key P Diagram | filling "What Why" | filling Controls | filling Key Noise | filling Control Measures | filling Measures

Ready 75%

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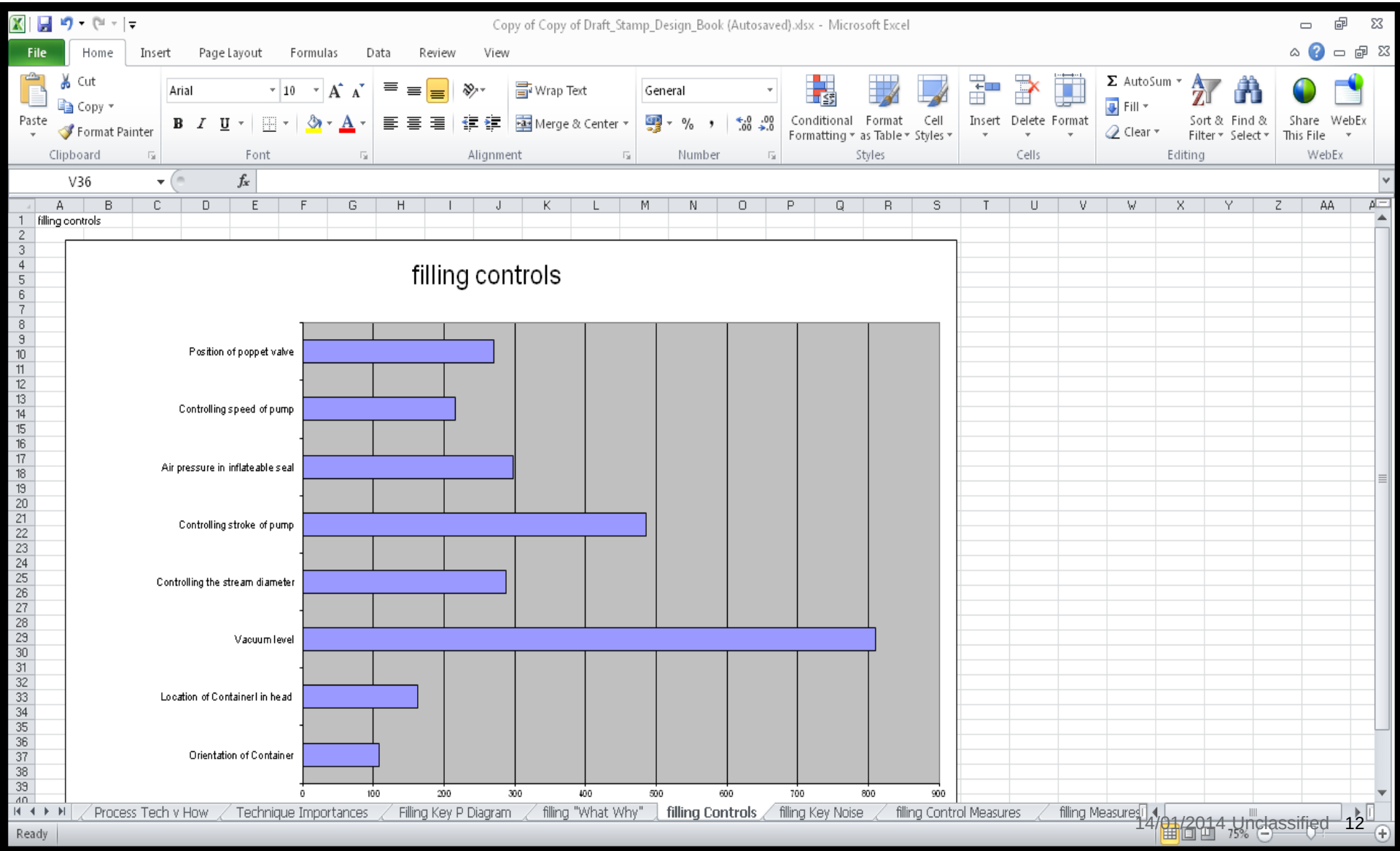
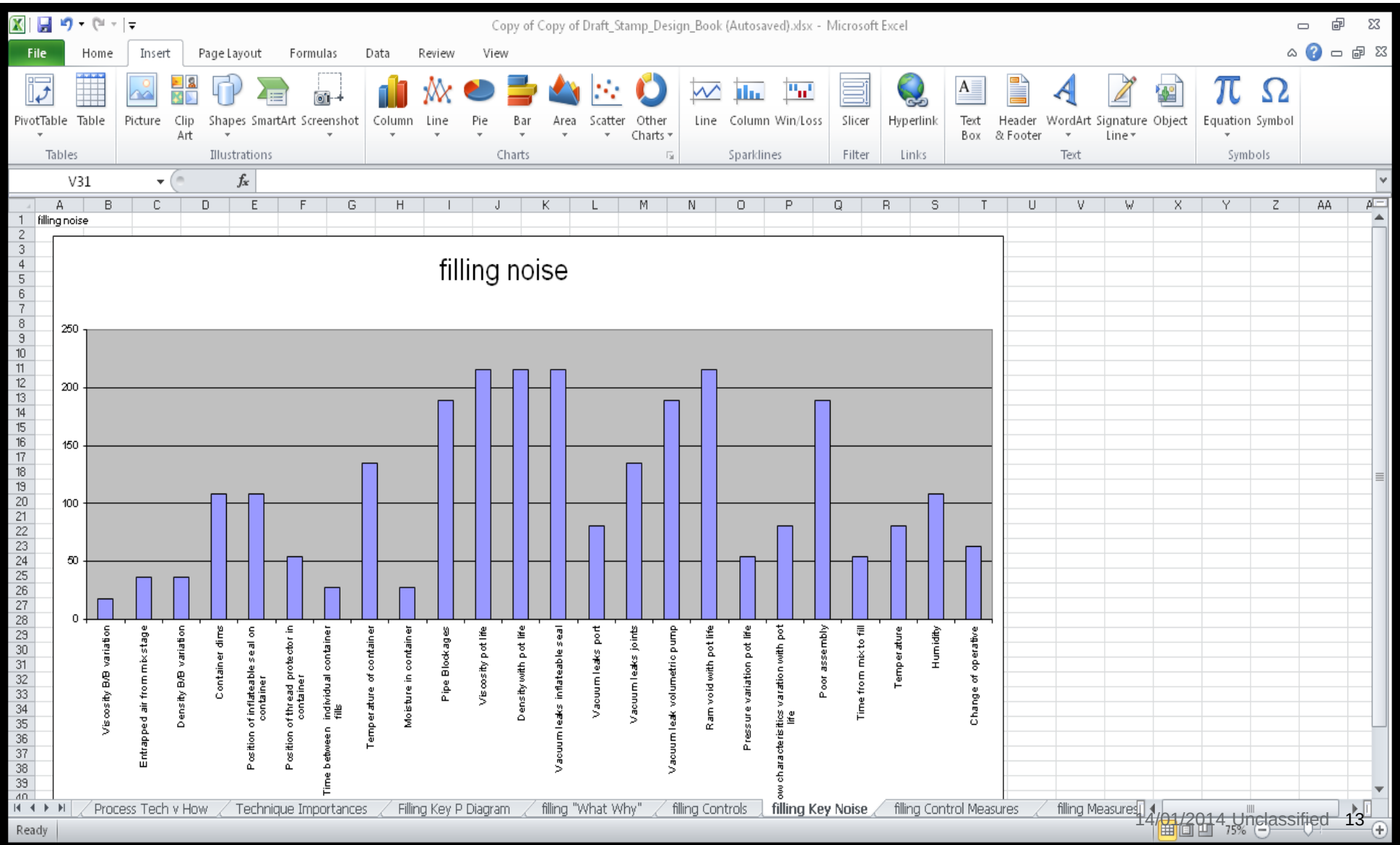
Relative Importance of Controls

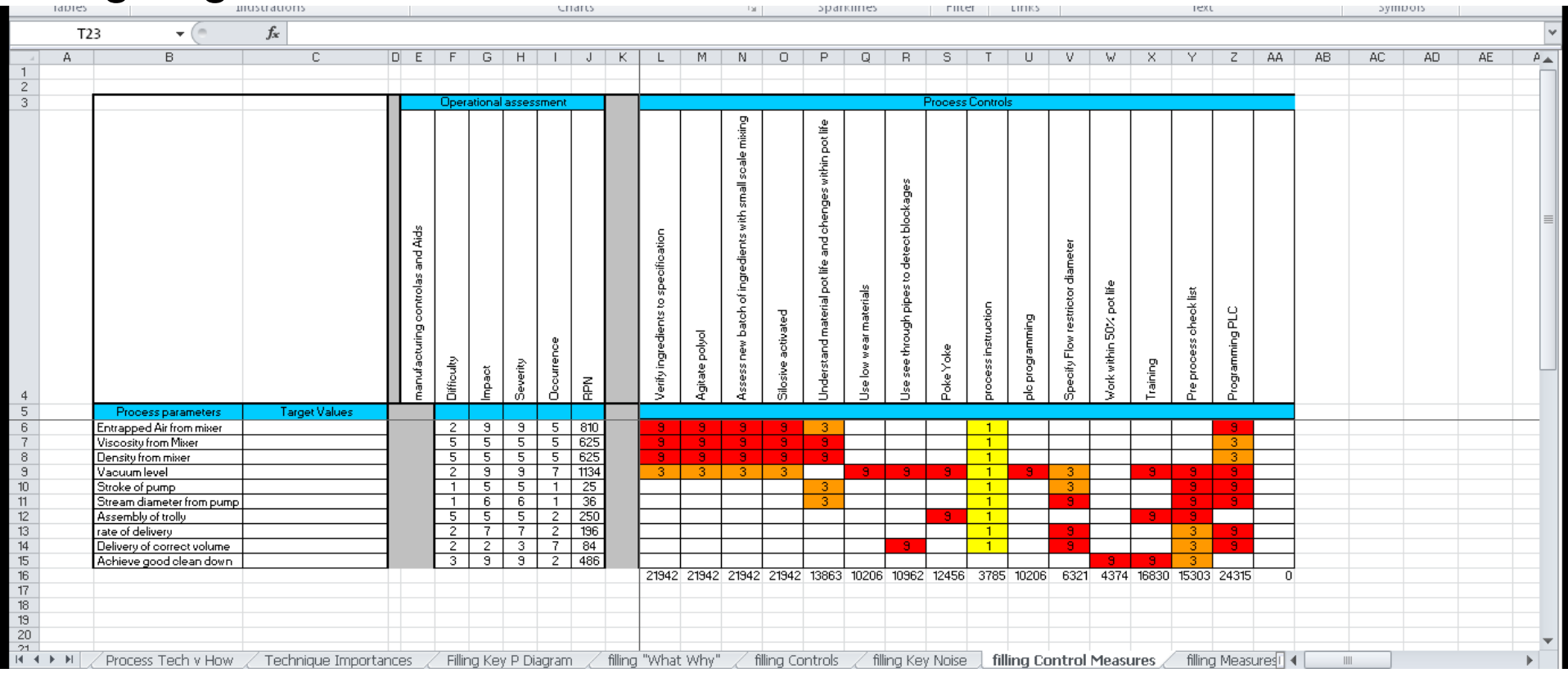


Relative Importance of Noises



Controls.

- Now in a review I want to see the means of control we are going to exercise.



		Operational assessment						Process Controls																	
Process parameters	Target Values	manufacturing controlas and Aids	Difficulty	Impact	Severity	Occurrence	RPN	Verify ingredients to specification	Agitate polyol	Assess new batch of ingredients with small scale mixing	Silosive activated	Understand material pot life and chenges within pot life	Use low wear materials	Use see through pipes to detect blockages	Poke Yoke	process instruction	plc programming	Specify Flow restrictor diameter	Work within 50% pot life	Training	Pre process check list	Programming PLC		
Entrapped Air from mixer			2	9	9	5	810	9	9	9	9	3				1						9		
Viscosity from Mixer			5	5	5	5	625	9	9	9	9	9				1						3		
Density from mixer			5	5	5	5	625	9	9	9	9	9				1						3		
Vacuum level			2	9	9	7	1134	3	3	3	3		9	9	9	1	9	3		9	9	9		
Stroke of pump			1	5	5	1	25					3				1		3			9	9		
Stream diameter from pump			1	6	6	1	36					3				1		9			9	9		
Assembly of trolly			5	5	5	2	250								9	1				9	9			
rate of delivery			2	7	7	2	196									1		9			3	9		
Delivery of correct volume			2	2	3	7	84							9		1		9			3	9		
Achieve good clean down			3	9	9	2	486												9	9	3			
								21942	21942	21942	21942	13863	10206	10962	12456	3785	10206	6321	4374	16830	15303	24315	0	

Process Tech v How | Technique Importances | Filling Key P Diagram | filling "What Why" | filling Controls | filling Key Noise | filling Control Measures | filling Measures

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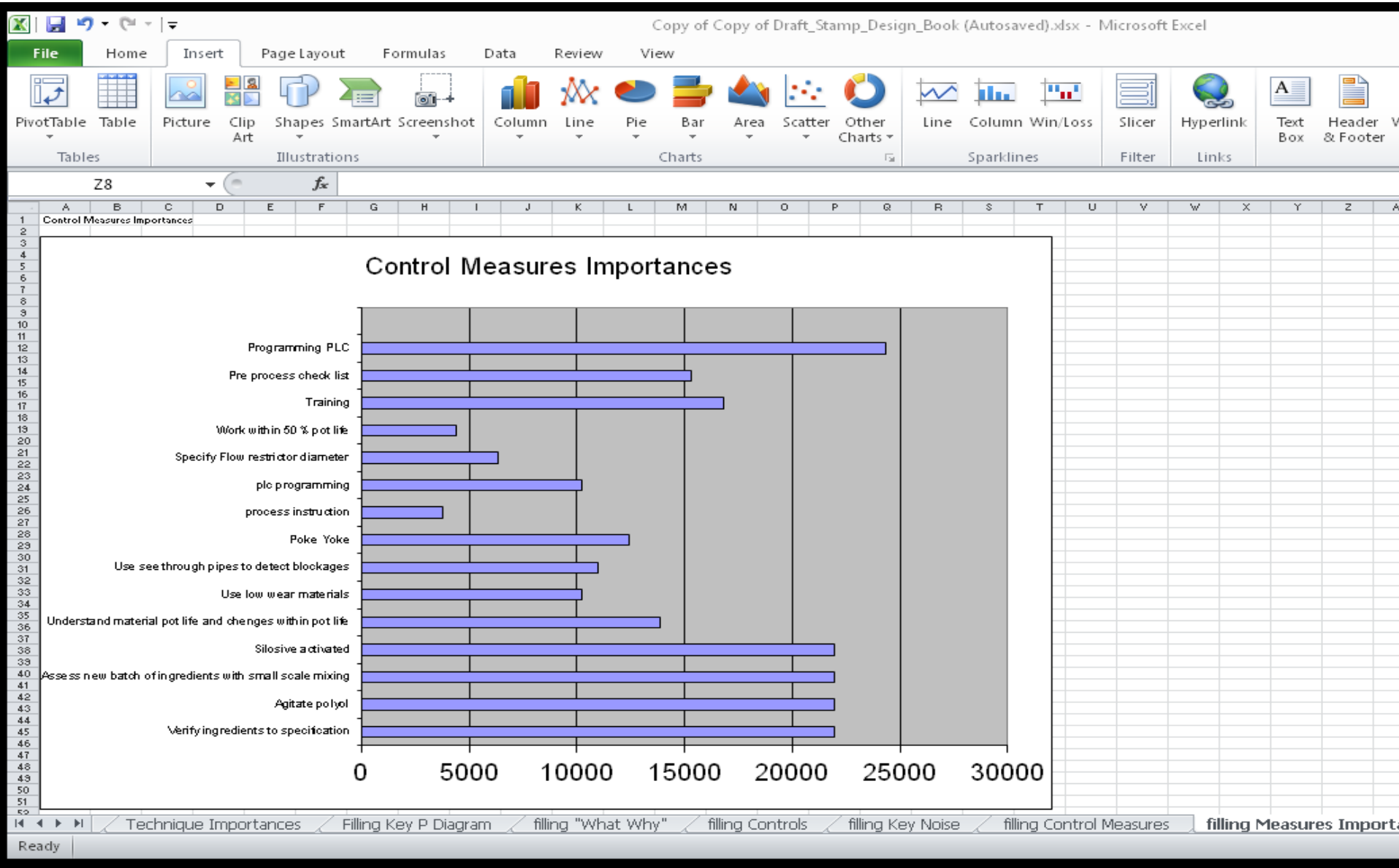
Control 2



Computer Control…….Control taken for granted?

- Remember this slide?
  - Reaction of the team to questioning at review was “Don’t worry about that, it’s all computer controlled!”
  - My questions were as follows
    - “What are we controlling?
    - How are we controlling it?
    - What happens when the control actions go wrong?”
    - “Are we controlling the right things?”
    - “Is there anything missing?”
  - Where do we start?
- Well at least we know what we are controlling via the PLC. Bur how are we doing it and is there anything missing.

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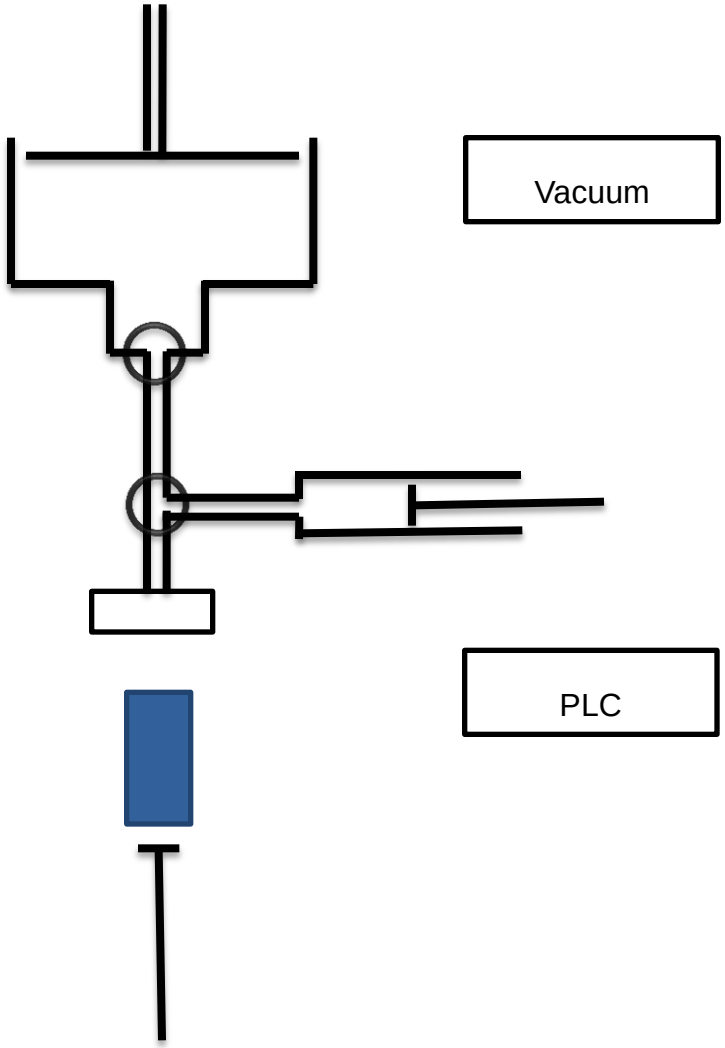
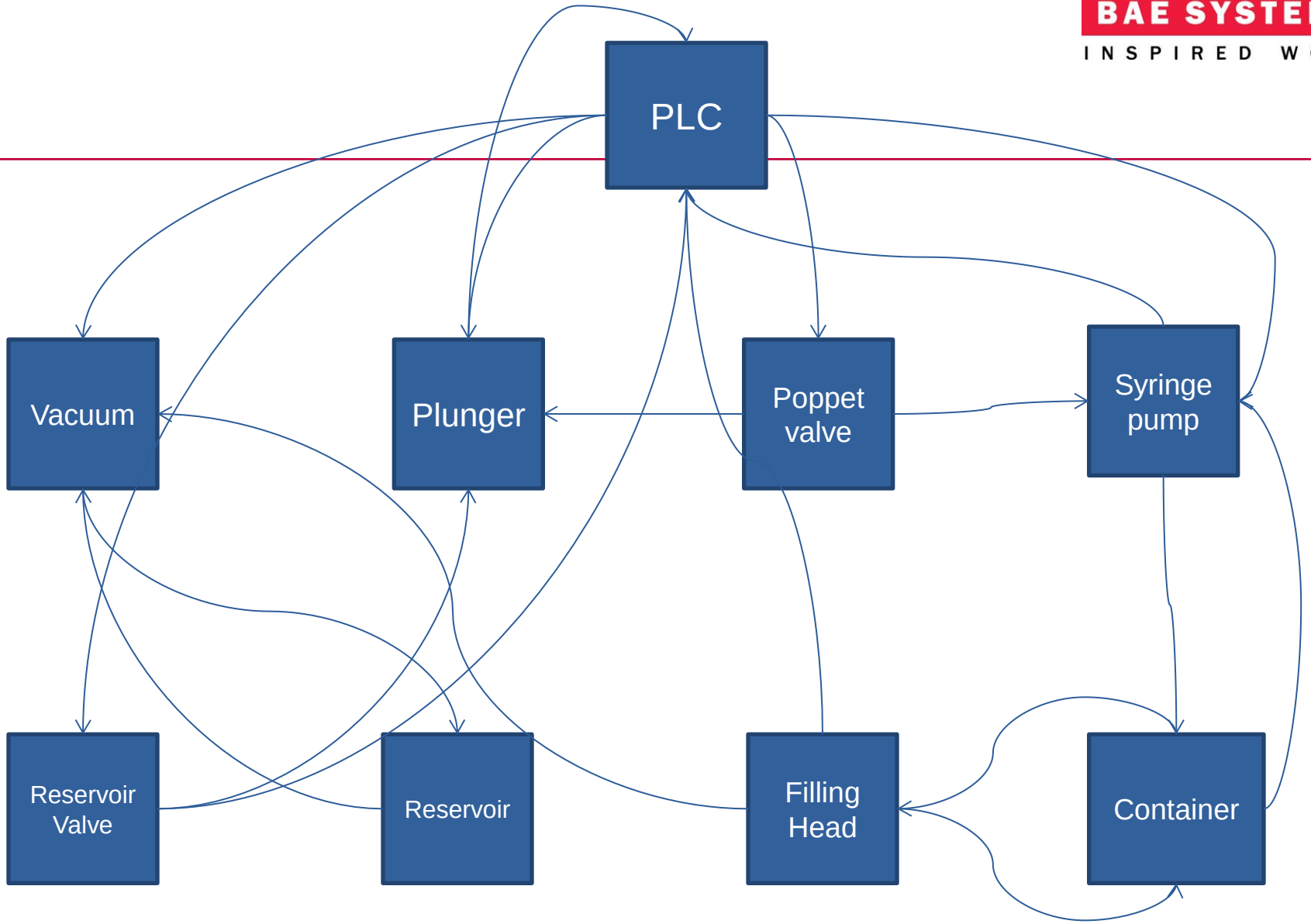
Develop the control “map”.

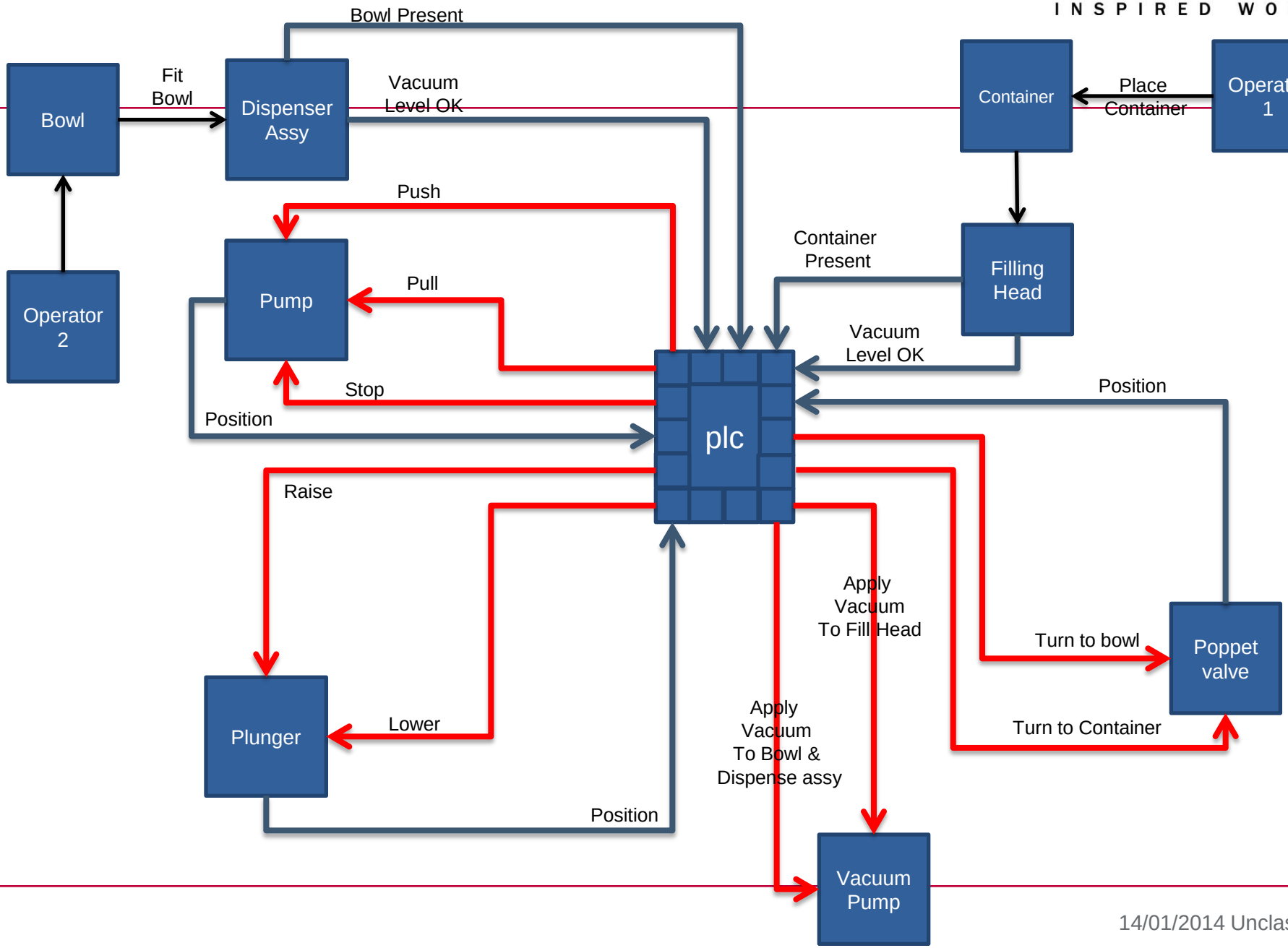
- Schematic.
  - Pen picture of the operation of the dispenser.
- Relationship Network.
  - How do all the component parts of this device come together to deliver the product.
- Command network.
  - How to we tell the component parts when to perform their function
  - ……..And when to stop.

Schematic



1. Bowl to plunger
2. Vac applied to bowl
3. Container raised to header
4. Vac applied to system
5. Poppet valve to bowl
6. Bowl valve open
7. Piston withdraws
8. Piston stop
9. Poppet valve to Container
10. Piston pushes
11. Piston stops
12. Poppet valve to bowl
13. Containerl lowers
14. Container removed
15. Container reload


PLC
Vacuum
Plunger
Poppet valve
Syringe pump
Reservoir Valve
Reservoir
Filling Head
Container


Bowl Present
Bowl
Fit Bowl
Dispenser Assy
Vacuum Level OK
Container
Place Container
Operator 1
Push
Pump
Pull
Container Present
Filling Head
Operator 2
Vacuum Level OK
Stop
Position
plc
Position
Raise
Apply Vacuum To Fill Head
Turn to bowl
Poppet valve
Plunger
Lower
Apply Vacuum To Bowl & Dispense assy
Turn to Container
Position
Vacuum Pump

What are The Top Level, System Accident Scenarios?

Design Requirements

System Level Accident	Loss of capability due to Catastrophic Failure
System Level Hazard	Catastrophic Failure
System level safety constraints.	No Catastrophic explosion = No cavities = Correct filling

Process Requirements

System Level Accident	Loss of capability due to Catastrophic Failure in facility
System Level Hazard	Catastrophic Failure during filling
System level safety constraints.	No leaks, No Blockages, Slurry within pot life, Effective clean down, No Contamination.

Analysis

- We then discussed our command actions in the control system one by one, asking the questions.
  - What happens if……
    - Command not given.
    - Unsafe command given.
    - Too long.
    - Too short.
    - Too late.
    - Too Early.
- We recorded any actions that would resolve any issues. Tried to be consistent so we could ascertain if one action would hit many issues.
- Also included an index according to the probability, severity and of ability to detect (on the current design) the consequences of issues stemming from the above. Analysis.

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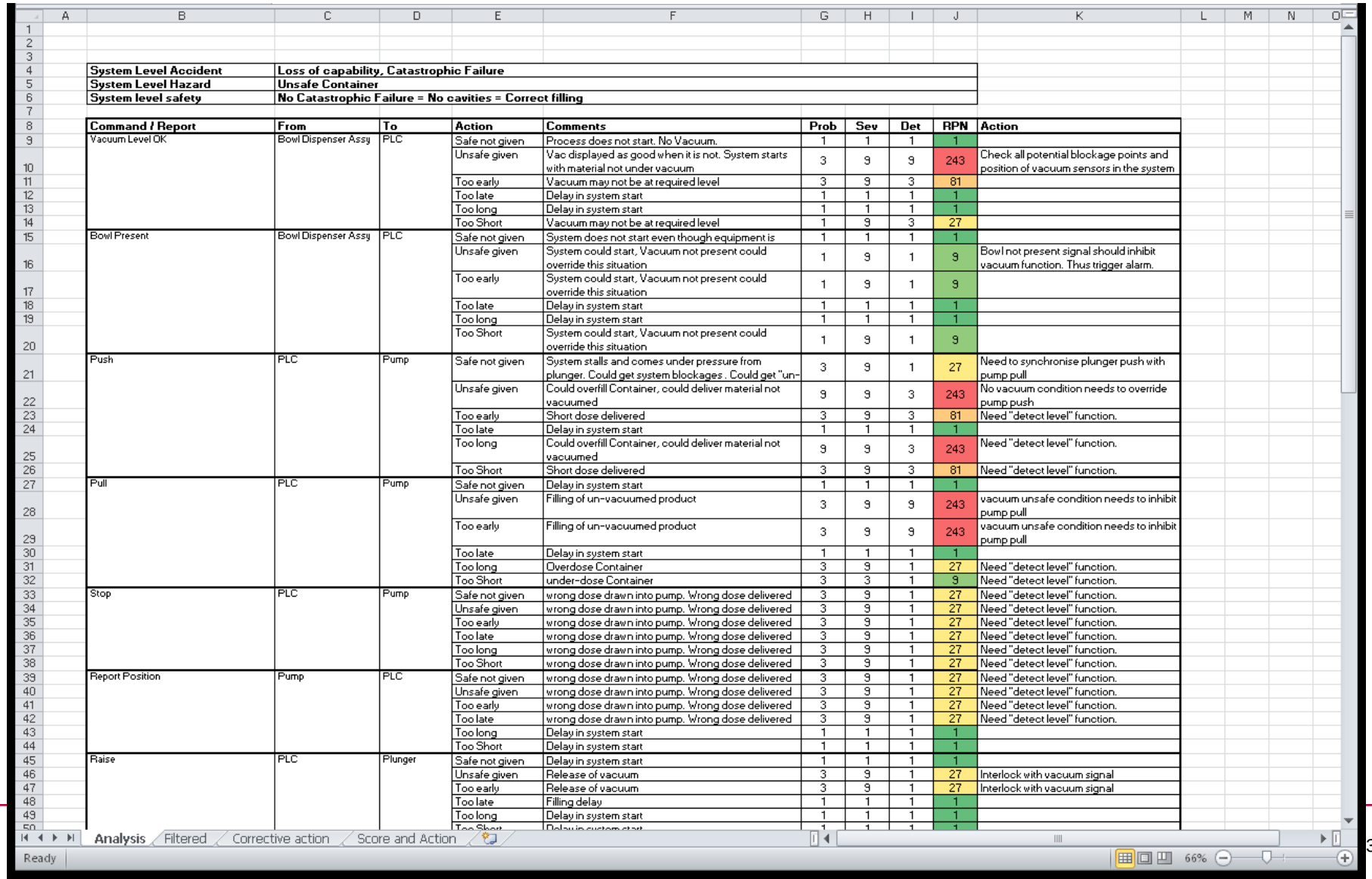
Analysis 2



System Level Accident	**Loss of capability, Catastrophic Failure**
System Level Hazard	**Unsafe Container**
System level safety	**No Catastrophic Failure = No cavities = Correct filling**

Command / Report	From	To	Action	Comments	Prob	Sev	Det	RPN	Action
Vacuum Level OK	Bowl Dispenser Assy	PLC	Safe not given	Process does not start. No Vacuum.	1	1	1	1	
			Unsafe given	Vac displayed as good when it is not. System starts with material not under vacuum	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
			Too early	Vacuum may not be at required level	3	9	3	81	
			Too late	Delay in system start	1	1	1	1	
			Too long	Delay in system start	1	1	1	1	
			Too Short	Vacuum may not be at required level	1	9	3	27	
Bowl Present	Bowl Dispenser Assy	PLC	Safe not given	System does not start even though equipment is	1	1	1	1	
			Unsafe given	System could start, Vacuum not present could override this situation	1	9	1	9	Bowl not present signal should inhibit vacuum function. Thus trigger alarm.
			Too early	System could start, Vacuum not present could override this situation	1	9	1	9	
			Too late	Delay in system start	1	1	1	1	
			Too long	Delay in system start	1	1	1	1	
			Too Short	System could start, Vacuum not present could override this situation	1	9	1	9	
Push	PLC	Pump	Safe not given	System stalls and comes under pressure from plunger. Could get system blockages . Could get "un-	3	9	1	27	Need to synchronise plunger push with pump pull
			Unsafe given	Could overfill Container, could deliver material not vacuumed	9	9	3	243	No vacuum condition needs to override pump push
			Too early	Short dose delivered	3	9	3	81	Need "detect level" function.
			Too late	Delay in system start	1	1	1	1	
			Too long	Could overfill Container, could deliver material not vacuumed	9	9	3	243	Need "detect level" function.
			Too Short	Short dose delivered	3	9	3	81	Need "detect level" function.
Pull	PLC	Pump	Safe not given	Delay in system start	1	1	1	1	
			Unsafe given	Filling of un-vacuumed product	3	9	9	243	vacuum unsafe condition needs to inhibit pump pull
			Too early	Filling of un-vacuumed product	3	9	9	243	vacuum unsafe condition needs to inhibit pump pull
			Too late	Delay in system start	1	1	1	1	
			Too long	Overdose Container	3	9	1	27	Need "detect level" function.
			Too Short	under-dose Container	3	3	1	9	Need "detect level" function.
Stop	PLC	Pump	Safe not given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Unsafe given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Too early	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Too late	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Too long	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Too Short	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Report Position	Pump	PLC	Safe not given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Unsafe given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Too early	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Too late	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
			Too long	Delay in system start	1	1	1	1	
			Too Short	Delay in system start	1	1	1	1	
Raise	PLC	Plunger	Safe not given	Delay in system start	1	1	1	1	
			Unsafe given	Release of vacuum	3	9	1	27	Interlock with vacuum signal
			Too early	Release of vacuum	3	9	1	27	Interlock with vacuum signal
			Too late	Filling delay	1	1	1	1	
			Too long	Delay in system start	1	1	1	1	

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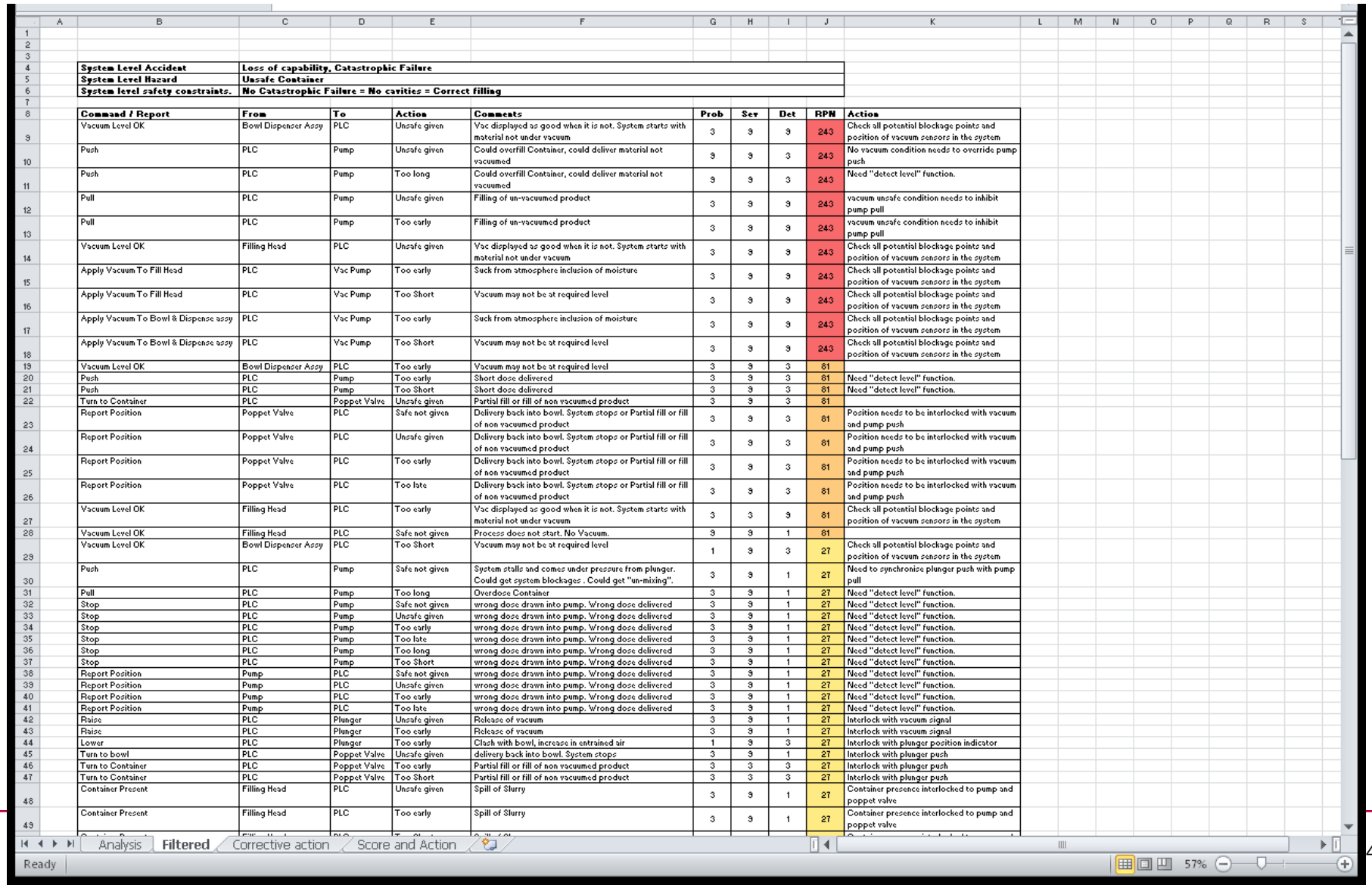
Analysis 3



System Level Accident	**Loss of capability, Catastrophic Failure**
System Level Hazard	**Unsafe Container**
System level safety constraints.	**No Catastrophic Failure = No cavities = Correct filling**

Command / Report	From	To	Action	Comments	Prob	Sev	Det	RPN	Action
Vacuum Level OK	Bowl Dispenser Assy	PLC	Unsafe given	Vac displayed as good when it is not. System starts with material not under vacuum	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Push	PLC	Pump	Unsafe given	Could overfill Container, could deliver material not vacuumed	9	9	3	243	No vacuum condition needs to override pump push
Push	PLC	Pump	Too long	Could overfill Container, could deliver material not vacuumed	9	9	3	243	Need "detect level" function.
Pull	PLC	Pump	Unsafe given	Filling of un-vacuumed product	3	9	9	243	vacuum unsafe condition needs to inhibit pump pull
Pull	PLC	Pump	Too early	Filling of un-vacuumed product	3	9	9	243	vacuum unsafe condition needs to inhibit pump pull
Vacuum Level OK	Filling Head	PLC	Unsafe given	Vac displayed as good when it is not. System starts with material not under vacuum	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Fill Head	PLC	Vac Pump	Too early	Suck from atmosphere inclusion of moisture	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Fill Head	PLC	Vac Pump	Too Short	Vacuum may not be at required level	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Bowl & Dispense assy	PLC	Vac Pump	Too early	Suck from atmosphere inclusion of moisture	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Bowl & Dispense assy	PLC	Vac Pump	Too Short	Vacuum may not be at required level	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Vacuum Level OK	Bowl Dispenser Assy	PLC	Too early	Vacuum may not be at required level	3	9	3	81	
Push	PLC	Pump	Too early	Short dose delivered	3	9	3	81	Need "detect level" function.
Push	PLC	Pump	Too Short	Short dose delivered	3	9	3	81	Need "detect level" function.
Turn to Container	PLC	Poppet Valve	Unsafe given	Partial fill or fill of non vacuumed product	3	9	3	81	
Report Position	Poppet Valve	PLC	Safe not given	Delivery back into bowl. System stops or Partial fill or fill of non vacuumed product	3	9	3	81	Position needs to be interlocked with vacuum and pump push
Report Position	Poppet Valve	PLC	Unsafe given	Delivery back into bowl. System stops or Partial fill or fill of non vacuumed product	3	9	3	81	Position needs to be interlocked with vacuum and pump push
Report Position	Poppet Valve	PLC	Too early	Delivery back into bowl. System stops or Partial fill or fill of non vacuumed product	3	9	3	81	Position needs to be interlocked with vacuum and pump push
Report Position	Poppet Valve	PLC	Too late	Delivery back into bowl. System stops or Partial fill or fill of non vacuumed product	3	9	3	81	Position needs to be interlocked with vacuum and pump push
Vacuum Level OK	Filling Head	PLC	Too early	Vac displayed as good when it is not. System starts with material not under vacuum	3	3	9	81	Check all potential blockage points and position of vacuum sensors in the system
Vacuum Level OK	Filling Head	PLC	Safe not given	Process does not start. No Vacuum.	9	9	1	81	
Vacuum Level OK	Bowl Dispenser Assy	PLC	Too Short	Vacuum may not be at required level	1	9	3	27	Check all potential blockage points and position of vacuum sensors in the system
Push	PLC	Pump	Safe not given	System stalls and comes under pressure from plunger. Could get system blockages . Could get "un-mixing".	3	9	1	27	Need to synchronise plunger push with pump pull
Pull	PLC	Pump	Too long	Overdose Container	3	9	1	27	Need "detect level" function.
Stop	PLC	Pump	Safe not given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Stop	PLC	Pump	Unsafe given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Stop	PLC	Pump	Too early	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Stop	PLC	Pump	Too late	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Stop	PLC	Pump	Too long	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Stop	PLC	Pump	Too Short	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Report Position	Pump	PLC	Safe not given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Report Position	Pump	PLC	Unsafe given	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Report Position	Pump	PLC	Too early	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Report Position	Pump	PLC	Too late	wrong dose drawn into pump. Wrong dose delivered	3	9	1	27	Need "detect level" function.
Raise	PLC	Plunger	Unsafe given	Release of vacuum	3	9	1	27	Interlock with vacuum signal
Raise	PLC	Plunger	Too early	Release of vacuum	3	9	1	27	Interlock with vacuum signal
Lower	PLC	Plunger	Too early	Clash with bowl, increase in entrained air	1	9	3	27	Interlock with plunger position indicator
Turn to bowl	PLC	Poppet Valve	Unsafe given	delivery back into bowl. System stops	3	9	1	27	Interlock with plunger push
Turn to Container	PLC	Poppet Valve	Too early	Partial fill or fill of non vacuumed product	3	3	3	27	Interlock with plunger push
Turn to Container	PLC	Poppet Valve	Too Short	Partial fill or fill of non vacuumed product	3	3	3	27	Interlock with plunger push
Container Present	Filling Head	PLC	Unsafe given	Spill of Slurry	3	9	1	27	Container presence interlocked to pump and poppet valve
Container Present	Filling Head	PLC	Too early	Spill of Slurry	3	9	1	27	Container presence interlocked to pump and poppet valve

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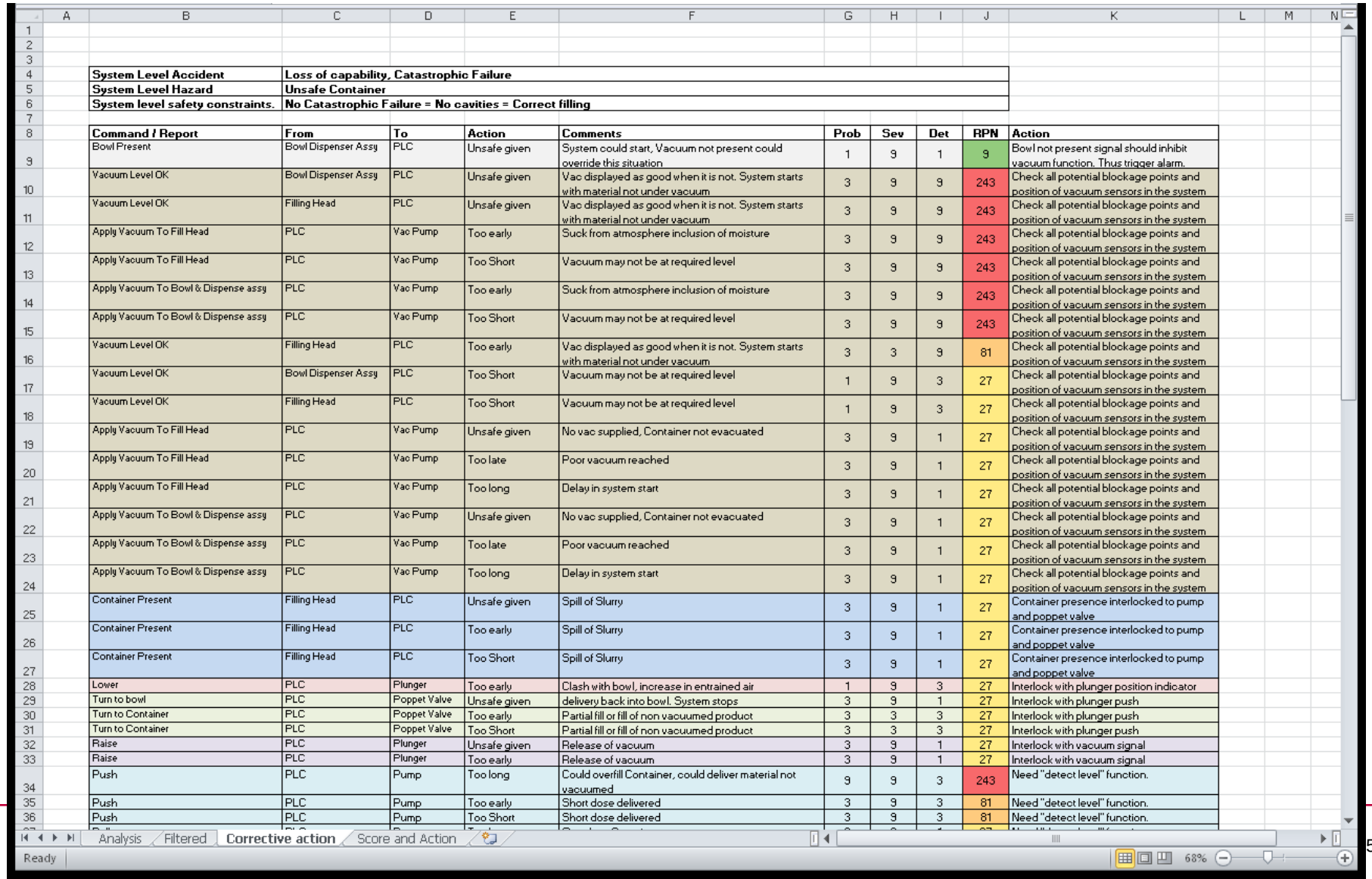
Analysis 4



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System level safety constraints.	**No Catastrophic Failure = No cavities = Correct filling**

Command / Report	From	To	Action	Comments	Prob	Sev	Det	RPN	Action
Bowl Present	Bowl Dispenser Assy	PLC	Unsafe given	System could start, Vacuum not present could override this situation	1	9	1	9	Bowl not present signal should inhibit vacuum function. Thus trigger alarm.
Vacuum Level OK	Bowl Dispenser Assy	PLC	Unsafe given	Vac displayed as good when it is not. System starts with material not under vacuum	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Vacuum Level OK	Filling Head	PLC	Unsafe given	Vac displayed as good when it is not. System starts with material not under vacuum	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Fill Head	PLC	Vac Pump	Too early	Suck from atmosphere inclusion of moisture	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Fill Head	PLC	Vac Pump	Too Short	Vacuum may not be at required level	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Bowl & Dispense assy	PLC	Vac Pump	Too early	Suck from atmosphere inclusion of moisture	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Bowl & Dispense assy	PLC	Vac Pump	Too Short	Vacuum may not be at required level	3	9	9	243	Check all potential blockage points and position of vacuum sensors in the system
Vacuum Level OK	Filling Head	PLC	Too early	Vac displayed as good when it is not. System starts with material not under vacuum	3	3	9	81	Check all potential blockage points and position of vacuum sensors in the system
Vacuum Level OK	Bowl Dispenser Assy	PLC	Too Short	Vacuum may not be at required level	1	9	3	27	Check all potential blockage points and position of vacuum sensors in the system
Vacuum Level OK	Filling Head	PLC	Too Short	Vacuum may not be at required level	1	9	3	27	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Fill Head	PLC	Vac Pump	Unsafe given	No vac supplied, Container not evacuated	3	9	1	27	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Fill Head	PLC	Vac Pump	Too late	Poor vacuum reached	3	9	1	27	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Fill Head	PLC	Vac Pump	Too long	Delay in system start	3	9	1	27	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Bowl & Dispense assy	PLC	Vac Pump	Unsafe given	No vac supplied, Container not evacuated	3	9	1	27	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Bowl & Dispense assy	PLC	Vac Pump	Too late	Poor vacuum reached	3	9	1	27	Check all potential blockage points and position of vacuum sensors in the system
Apply Vacuum To Bowl & Dispense assy	PLC	Vac Pump	Too long	Delay in system start	3	9	1	27	Check all potential blockage points and position of vacuum sensors in the system
Container Present	Filling Head	PLC	Unsafe given	Spill of Slurry	3	9	1	27	Container presence interlocked to pump and poppet valve
Container Present	Filling Head	PLC	Too early	Spill of Slurry	3	9	1	27	Container presence interlocked to pump and poppet valve
Container Present	Filling Head	PLC	Too Short	Spill of Slurry	3	9	1	27	Container presence interlocked to pump and poppet valve
Lower	PLC	Plunger	Too early	Clash with bowl, increase in entrained air	1	9	3	27	Interlock with plunger position indicator
Turn to bowl	PLC	Poppet Valve	Unsafe given	delivery back into bowl. System stops	3	9	1	27	Interlock with plunger push
Turn to Container	PLC	Poppet Valve	Too early	Partial fill or fill of non vacuumed product	3	3	3	27	Interlock with plunger push
Turn to Container	PLC	Poppet Valve	Too Short	Partial fill or fill of non vacuumed product	3	3	3	27	Interlock with plunger push
Raise	PLC	Plunger	Unsafe given	Release of vacuum	3	9	1	27	Interlock with vacuum signal
Raise	PLC	Plunger	Too early	Release of vacuum	3	9	1	27	Interlock with vacuum signal
Push	PLC	Pump	Too long	Could overfill Container, could deliver material not vacuumed	9	9	3	243	Need "detect level" function.
Push	PLC	Pump	Too early	Short dose delivered	3	9	3	81	Need "detect level" function.
Push	PLC	Pump	Too Short	Short dose delivered	3	9	3	81	Need "detect level" function.

Recommendations.

- Re-position vacuum sensors to remove the risk of a false “Vacuum achieved” signal.
- Redesign poppet valve to reduce chance of blockage.
- Insert “Detect full” feature.
- Insert link between plunger and piston so the piston does not try to push against the plunger.

BAE SYSTEMS
INSPIRED WORK

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