

First Experiences at Ineos Chlor Ltd. with GPC for Product Quality and Process Operations Improvement

Derek Armstrong, Mike Tyrrell,
Stephen Casey – Ineos Chlor Ltd.

Robin Brooks, Richard Thorpe, John
Wilson - Curvaceous Software Ltd.

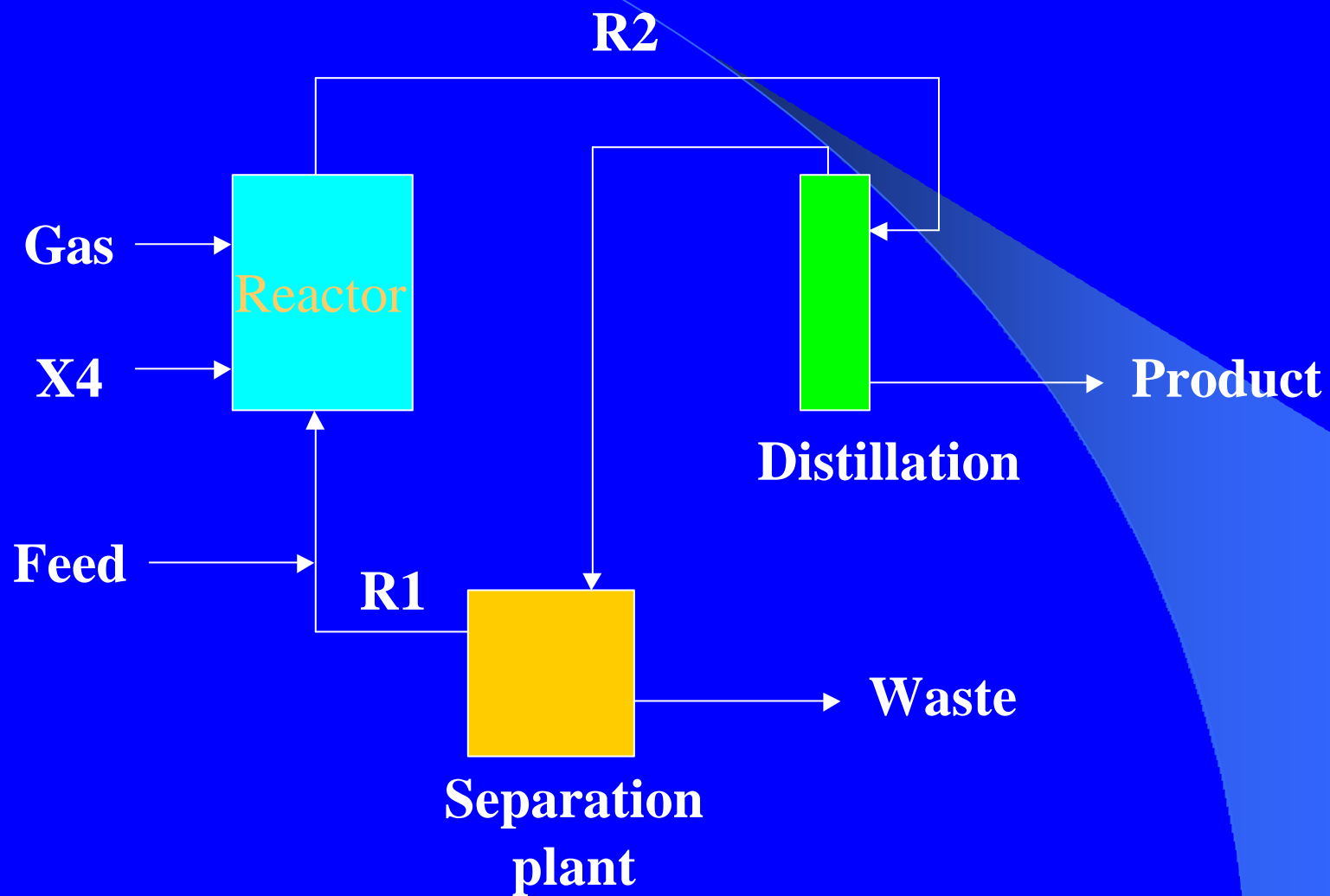
Summary of GPC Benefits

- A unifying mathematical framework for Process Alarms, Process Control and Product Quality Control.
- Immediate applicability in process improvement, production reporting, alarm rationalisation, controls assessment
- New operator display showing multi-variable process operating and quality violations in context.
- Geometric “no equations” model easily generated from process history data...Low maintenance costs so practical even for small plants with little or no engineering support
- Economic benefits from higher yields, increased throughput, lower unit costs AND increased safety

Field Trials

- IneosChlor, Runcorn, UK
 - Engineer assessment against existing alarms
 - Open-loop Operator Guidance
 - Product Quality Improvement
 - Process Operations Improvement

Ineos Chlor Plant, Runcorn, UK



A Brand-New Technology

- Does it do what it claims?
- Alarms
- Quality Improvement
- Operations Improvement
- Ease of use

The Project - Objectives

- Engineer assessment of new alarms compared to existing
 - “new alarms so good that they can be used to direct operators to achieve better yields and qualities”
- 10 days of documented operator usage
- Open-loop use of Advisory Algorithm in control room to improve KPI's
- Jointly authored publication of results

Results

- Alarms

- HiHI-LoLo Alarms

- Went from 51% correct to 90% correct on first attempt
 - Now much better still so less dependent solely on operator vigilance

- Hi-Lo Alarms

- Previously almost impossible to set at constant values
 - Now multi-variable alarms are so good they are advising operators where to operate and have warned of equipment damage long before any one variable detected a problem.

- Quality Improvement

- 2% immediate Process KPI Improvement
 - More expected as Operators gain more confidence and implement even more Advice
 - More expected when the Optimiser is turned on

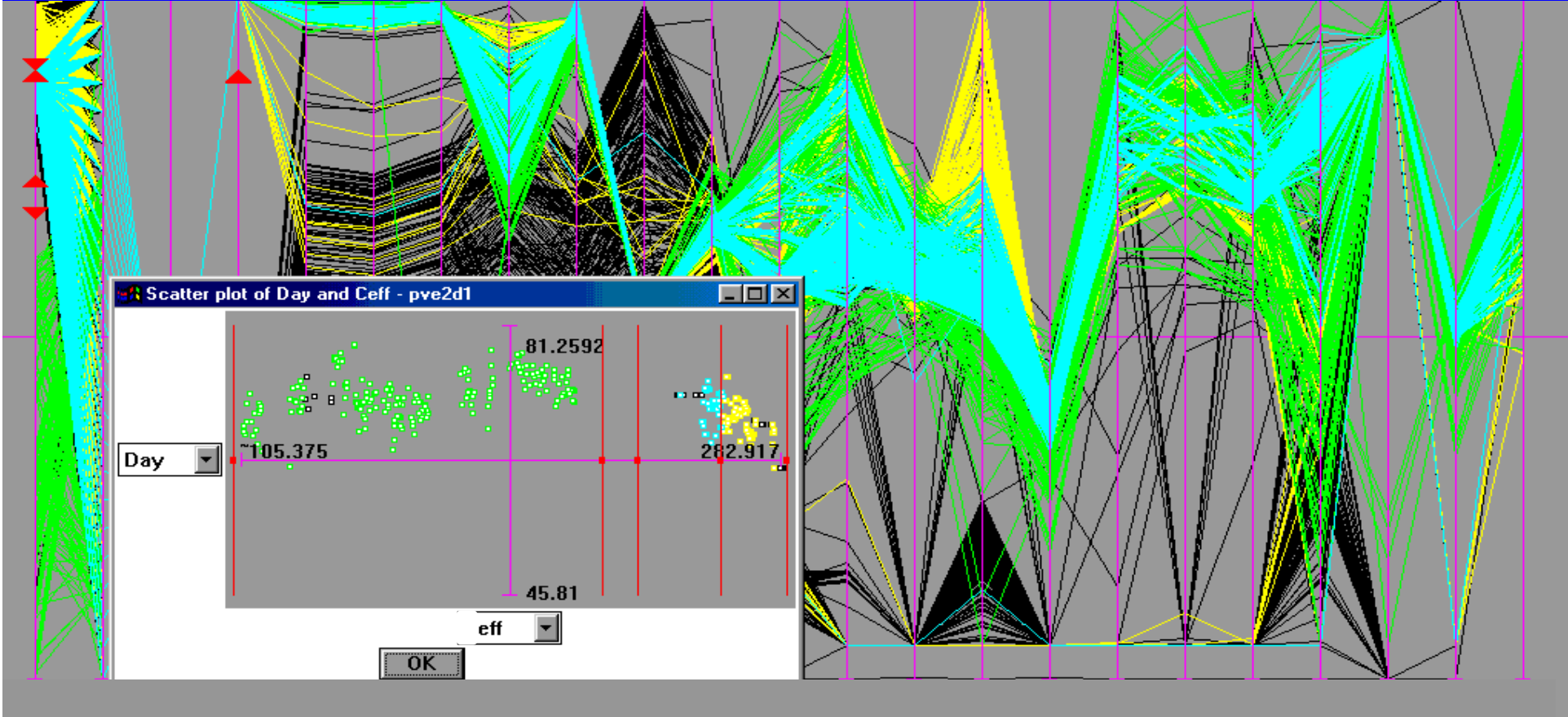
- Operations Improvement

- High acceptability of operator Advice
 - Advice also used to shorten start-up time by a factor of 6.

Ease of Use

- Visual Analysis for BOZ Definition led to many valuable and unexpected discoveries
- We can build a 40-variable non-linear interactive model and have it in use by an operator in less than a day
- We have never seen an equation!

High Efficiency had been achieved



Day Hour Rx Stat T1 T2 T3 T4 T5 T6 X1 X2 X3 Feed Gas R1 R2 R3 Steam R4 X4 Eff

Total size: 1768 Undisplayed edges: No Impossible query: No Focus level: 2

-Query

Creation Mode

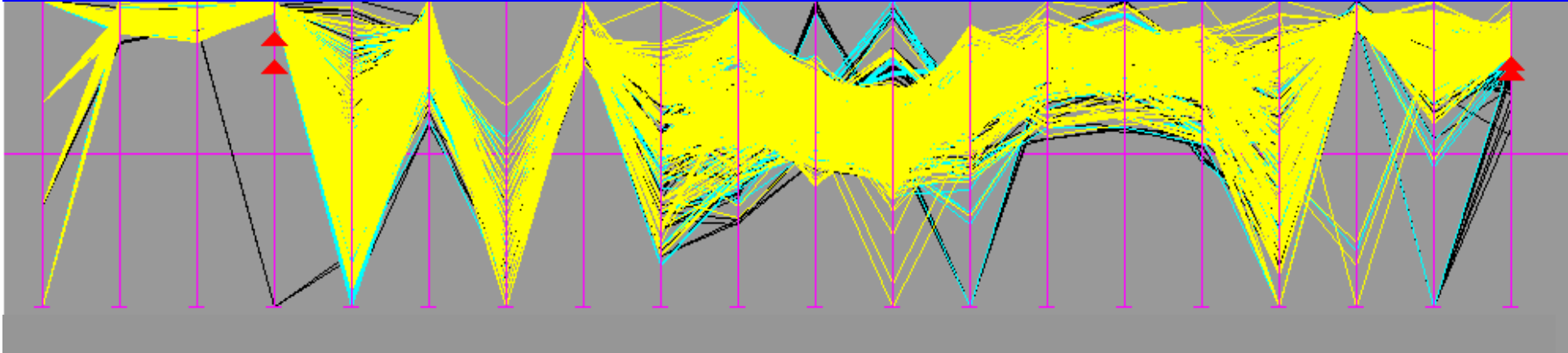
Pointer setting: Select

Combiner: And

Summary

	Color	Size	Percent	Visible	Name
Show many		190	11%	<input checked="" type="checkbox"/>	q3Reactor 2 pre July
		544	31%	<input checked="" type="checkbox"/>	q1Reactor 2 September October

Quality Achievement Contours



Day	Hour	Rx	Stat	T1	T2	T3	T4	T5	T6	X1	X2	X3	Feed	Gas	R1	R2	R3	Steam	R4	X4	Eff
-----	------	----	------	----	----	----	----	----	----	----	----	----	------	-----	----	----	----	-------	----	----	-----

Total size: 1149	Undisplayed edges: No	Impossible query: No	Focus level: 2
------------------	-----------------------	----------------------	----------------

Query _____

Creation Mode	Summary
---------------	---------

Pointer setting: Select Color Size Percent Visible Name

Combiner: And Show many: 051 00% 077 85% 084 100% 091 100% 098 100% 105 100% 112 100% 119 100% 126 100% 133 100% 140 100% 147 100% 154 100% 161 100% 168 100% 175 100% 182 100% 189 100% 196 100% 203 100% 210 100% 217 100% 224 100% 231 100% 238 100% 245 100% 252 100% 259 100% 266 100% 273 100% 280 100% 287 100% 294 100% 301 100% 308 100% 315 100% 322 100% 329 100% 336 100% 343 100% 350 100% 357 100% 364 100% 371 100% 378 100% 385 100% 392 100% 399 100% 406 100% 413 100% 420 100% 427 100% 434 100% 441 100% 448 100% 455 100% 462 100% 469 100% 476 100% 483 100% 490 100% 497 100% 504 100% 511 100% 518 100% 525 100% 532 100% 539 100% 546 100% 553 100% 560 100% 567 100% 574 100% 581 100% 588 100% 595 100% 602 100% 609 100% 616 100% 623 100% 630 100% 637 100% 644 100% 651 100% 658 100% 665 100% 672 100% 679 100% 686 100% 693 100% 700 100% 707 100% 714 100% 721 100% 728 100% 735 100% 742 100% 749 100% 756 100% 763 100% 770 100% 777 100% 784 100% 791 100% 798 100% 805 100% 812 100% 819 100% 826 100% 833 100% 840 100% 847 100% 854 100% 861 100% 868 100% 875 100% 882 100% 889 100% 896 100% 903 100% 910 100% 917 100% 924 100% 931 100% 938 100% 945 100% 952 100% 959 100% 966 100% 973 100% 980 100% 987 100% 994 100% 1001 100% 1008 100% 1015 100% 1022 100% 1029 100% 1036 100% 1043 100% 1050 100% 1057 100% 1064 100% 1071 100% 1078 100% 1085 100% 1092 100% 1099 100% 1106 100% 1113 100% 1120 100% 1127 100% 1134 100% 1141 100% 1148 100% 1155 100% 1162 100% 1169 100% 1176 100% 1183 100% 1190 100% 1197 100% 1204 100% 1211 100% 1218 100% 1225 100% 1232 100% 1239 100% 1246 100% 1253 100% 1260 100% 1267 100% 1274 100% 1281 100% 1288 100% 1295 100% 1302 100% 1309 100% 1316 100% 1323 100% 1330 100% 1337 100% 1344 100% 1351 100% 1358 100% 1365 100% 1372 100% 1379 100% 1386 100% 1393 100% 1400 100% 1407 100% 1414 100% 1421 100% 1428 100% 1435 100% 1442 100% 1449 100% 1456 100% 1463 100% 1470 100% 1477 100% 1484 100% 1491 100% 1498 100% 1505 100% 1512 100% 1519 100% 1526 100% 1533 100% 1540 100% 1547 100% 1554 100% 1561 100% 1568 100% 1575 100% 1582 100% 1589 100% 1596 100% 1603 100% 1610 100% 1617 100% 1624 100% 1631 100% 1638 100% 1645 100% 1652 100% 1659 100% 1666 100% 1673 100% 1680 100% 1687 100% 1694 100% 1701 100% 1708 100% 1715 100% 1722 100% 1729 100% 1736 100% 1743 100% 1750 100% 1757 100% 1764 100% 1771 100% 1778 100% 1785 100% 1792 100% 1799 100% 1806 100% 1813 100% 1820 100% 1827 100% 1834 100% 1841 100% 1848 100% 1855 100% 1862 100% 1869 100% 1876 100% 1883 100% 1890 100% 1897 100% 1904 100% 1911 100% 1918 100% 1925 100% 1932 100% 1939 100% 1946 100% 1953 100% 1960 100% 1967 100% 1974 100% 1981 100% 1988 100% 1995 100% 2002 100% 2009 100% 2016 100% 2023 100% 2030 100% 2037 100% 2044 100% 2051 100% 2058 100% 2065 100% 2072 100% 2079 100% 2086 100% 2093 100% 2100 100% 2107 100% 2114 100% 2121 100% 2128 100% 2135 100% 2142 100% 2149 100% 2156 100% 2163 100% 2170 100% 2177 100% 2184 100% 2191 100% 2198 100% 2205 100% 2212 100% 2219 100% 2226 100% 2233 100% 2240 100% 2247 100% 2254 100% 2261 100% 2268 100% 2275 100% 2282 100% 2289 100% 2296 100% 2303 100% 2310 100% 2317 100% 2324 100% 2331 100% 2338 100% 2345 100% 2352 100% 2359 100% 2366 100% 2373 100% 2380 100% 2387 100% 2394 100% 2401 100% 2408 100% 2415 100% 2422 100% 2429 100% 2436 100% 2443 100% 2450 100% 2457 100% 2464 100% 2471 100% 2478 100% 2485 100% 2492 100% 2499 100% 2506 100% 2513 100% 2520 100% 2527 100% 2534 100% 2541 100% 2548 100% 2555 100% 2562 100% 2569 100% 2576 100% 2583 100% 2590 100% 2597 100% 2604 100% 2611 100% 2618 100% 2625 100% 2632 100% 2639 100% 2646 100% 2653 100% 2660 100% 2667 100% 2674 100% 2681 100% 2688 100% 2695 100% 2702 100% 2709 100% 2716 100% 2723 100% 2730 100% 2737 100% 2744 100% 2751 100% 2758 100% 2765 100% 2772 100% 2779 100% 2786 100% 2793 100% 2800 100% 2807 100% 2814 100% 2821 100% 2828 100% 2835 100% 2842 100% 2849 100% 2856 100% 2863 100% 2870 100% 2877 100% 2884 100% 2891 100% 2898 100% 2905 100% 2912 100% 2919 100% 2926 100% 2933 100% 2940 100% 2947 100% 2954 100% 2961 100% 2968 100% 2975 100% 2982 100% 2989 100% 2996 100% 300

Combiner: And Show many: 051 00% 077 85% 084 100% 091 100% 098 100% 105 100% 112 100% 119 100% 126 100% 133 100% 140 100% 147 100% 154 100% 161 100% 168 100% 175 100% 182 100% 189 100% 196 100% 203 100% 210 100% 217 100% 224 100% 231 100% 238 100% 245 100% 252 100% 259 100% 266 100% 273 100% 280 100% 287 100% 294 100% 301 100% 308 100% 315 100% 322 100% 329 100% 336 100% 343 100% 350 100% 357 100% 364 100% 371 100% 378 100% 385 100% 392 100% 399 100% 406 100% 413 100% 420 100% 427 100% 434 100% 441 100% 448 100% 455 100% 462 100% 469 100% 476 100% 483 100% 490 100% 497 100% 504 100% 511 100% 518 100% 525 100% 532 100% 539 100% 546 100% 553 100% 560 100% 567 100% 574 100% 581 100% 588 100% 595 100% 602 100% 609 100% 616 100% 623 100% 630 100% 637 100% 644 100% 651 100% 658 100% 665 100% 672 100% 679 100% 686 100% 693 100% 700 100% 707 100% 714 100% 721 100% 728 100% 735 100% 742 100% 749 100% 756 100% 763 100% 770 100% 777 100% 784 100% 791 100% 798 100% 805 100% 812 100% 819 100% 826 100% 833 100% 840 100% 847 100% 854 100% 861 100% 868 100% 875 100% 882 100% 889 100% 896 100% 903 100% 910 100% 917 100% 924 100% 931 100% 938 100% 945 100% 952 100% 959 100% 966 100% 973 100% 980 100% 987 100% 994 100% 1001 100% 1008 100% 1015 100% 1022 100% 1029 100% 1036 100% 1043 100% 1050 100% 1057 100% 1064 100% 1071 100% 1078 100% 1085 100% 1092 100% 1099 100% 1106 100% 1113 100% 1120 100% 1127 100% 1134 100% 1141 100% 1148 100% 1155 100% 1162 100% 1169 100% 1176 100% 1183 100% 1190 100% 1197 100% 1204 100% 1211 100% 1218 100% 1225 100% 1232 100% 1239 100% 1246 100% 1253 100% 1260 100% 1267 100% 1274 100% 1281 100% 1288 100% 1295 100% 1302 100% 1309 100% 1316 100% 1323 100% 1330 100% 1337 100% 1344 100% 1351 100% 1358 100% 1365 100% 1372 100% 1379 100% 1386 100% 1393 100% 1400 100% 1407 100% 1414 100% 1421 100% 1428 100% 1435 100% 1442 100% 1449 100% 1456 100% 1463 100% 1470 100% 1477 100% 1484 100% 1491 100% 1498 100% 1505 100% 1512 100% 1519 100% 1526 100% 1533 100% 1540 100% 1547 100% 1554 100% 1561 100% 1568 100% 1575 100% 1582 100% 1589 100% 1596 100% 1603 100% 1610 100% 1617 100% 1624 100% 1631 100% 1638 100% 1645 100% 1652 100% 1659 100% 1666 100% 1673 100% 1680 100% 1687 100% 1694 100% 1701 100% 1708 100% 1715 100% 1722 100% 1729 100% 1736 100% 1743 100% 1750 100% 1757 100% 1764 100% 1771 100% 1778 100% 1785 100% 1792 100% 1799 100% 1806 100% 1813 100% 1820 100% 1827 100% 1834 100% 1841 100% 1848 100% 1855 100% 1862 100% 1869 100% 1876 100% 1883 100% 1890 100% 1897 100% 1904 100% 1911 100% 1918 100% 1925 100% 1932 100% 1939 100% 1946 100% 1953 100% 1960 100% 1967 100% 1974 100% 1981 100% 1988 100% 1995 100% 2002 100% 2009 100% 2016 100% 2023 100% 2030 100% 2037 100% 2044 100% 2051 100% 2058 100% 2065 100% 2072 100% 2079 100% 2086 100% 2093 100% 2100 100% 2107 100% 2114 100% 2121 100% 2128 100% 2135 100% 2142 100% 2149 100% 2156 100% 2163 100% 2170 100% 2177 100% 2184 100% 2191 100% 2198 100% 2205 100% 2212 100% 2219 100% 2226 100% 2233 100% 2240 100% 2247 100% 2254 100% 2261 100% 2268 100% 2275 100% 2282 100% 2289 100% 2296 100% 2303 100% 2310 100% 2317 100% 2324 100% 2331 100% 2338 100% 2345 100% 2352 100% 2359 100% 2366 100% 2373 100% 2380 100% 2387 100% 2394 100% 2401 100% 2408 100% 2415 100% 2422 100% 2429 100% 2436 100% 2443 100% 2450 100% 2457 100% 2464 100% 2471 100% 2478 100% 2485 100% 2492 100% 2499 100% 2506 100% 2513 100% 2520 100% 2527 100% 2534 100% 2541 100% 2548 100% 2555 100% 2562 100% 2569 100% 2576 100% 2583 100% 2590 100% 2597 100% 2604 100% 2611 100% 2618 100% 2625 100% 2632 100% 2639 100% 2646 100% 2653 100% 2660 100% 2667 100% 2674 100% 2681 100% 2688 100% 2695 100% 2702 100% 2709 100% 2716 100% 2723 100% 2730 100% 2737 100% 2744 100% 2751 100% 2758 100% 2765 100% 2772 100% 2779 100% 2786 100% 2793 100% 2800 100% 2807 100% 2814 100% 2821 100% 2828 100% 2835 100% 2842 100% 2849 100% 2856 100% 2863 100% 2870 100% 2877 100% 2884 100% 2891 100% 2898 100% 2905 100% 2912 100% 2919 100% 2926 100% 2933 100% 2940 100% 2947 100% 2954 100% 2961 100% 2968 100% 2975 100% 2982 100% 2989 100% 2996 100% 300

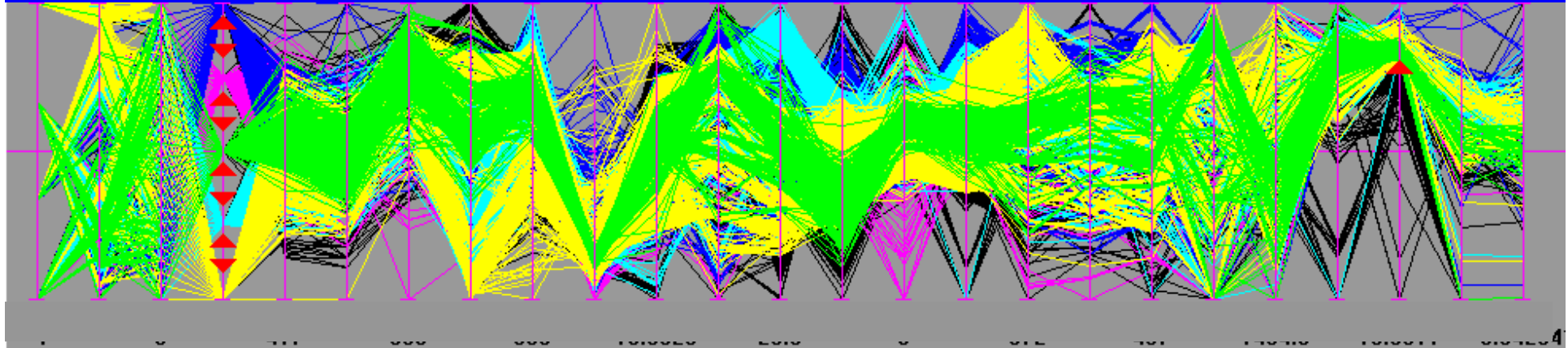
Creation Mode	Summary
---------------	---------

Pointer setting: Select Color Size Percent Visible Name

Combiner:	And	Show many	691	60%	<input checked="" type="checkbox"/>	q	:ff_gt_70
			977	85%	<input checked="" type="checkbox"/>	q	:ff_gt_68

Comparing Identical Reactors

May01-Jan02, Eff > 68%, all reactors



Code Day Hour Rx Stat T1 T2 T3 T4 T5 T6 X1 X2 X3 Feed Gas R1 R2 R3 Steam R4 X4 Eff C1 C2
Total size: 4440 Undisplayed edges: No Impossible query: No Focus level: 2

Query		Summary				
Creation Mode	Pointer setting:	Color	Size	Percent	Visible	Name
	Select		832	19%	<input checked="" type="checkbox"/>	q1Reactor_5_eff_gt_68_Selectivity_81_pct
Combiner:	And		956	22%	<input checked="" type="checkbox"/>	q1Reactor_4_eff_gt_68_Selectivity_91_pct

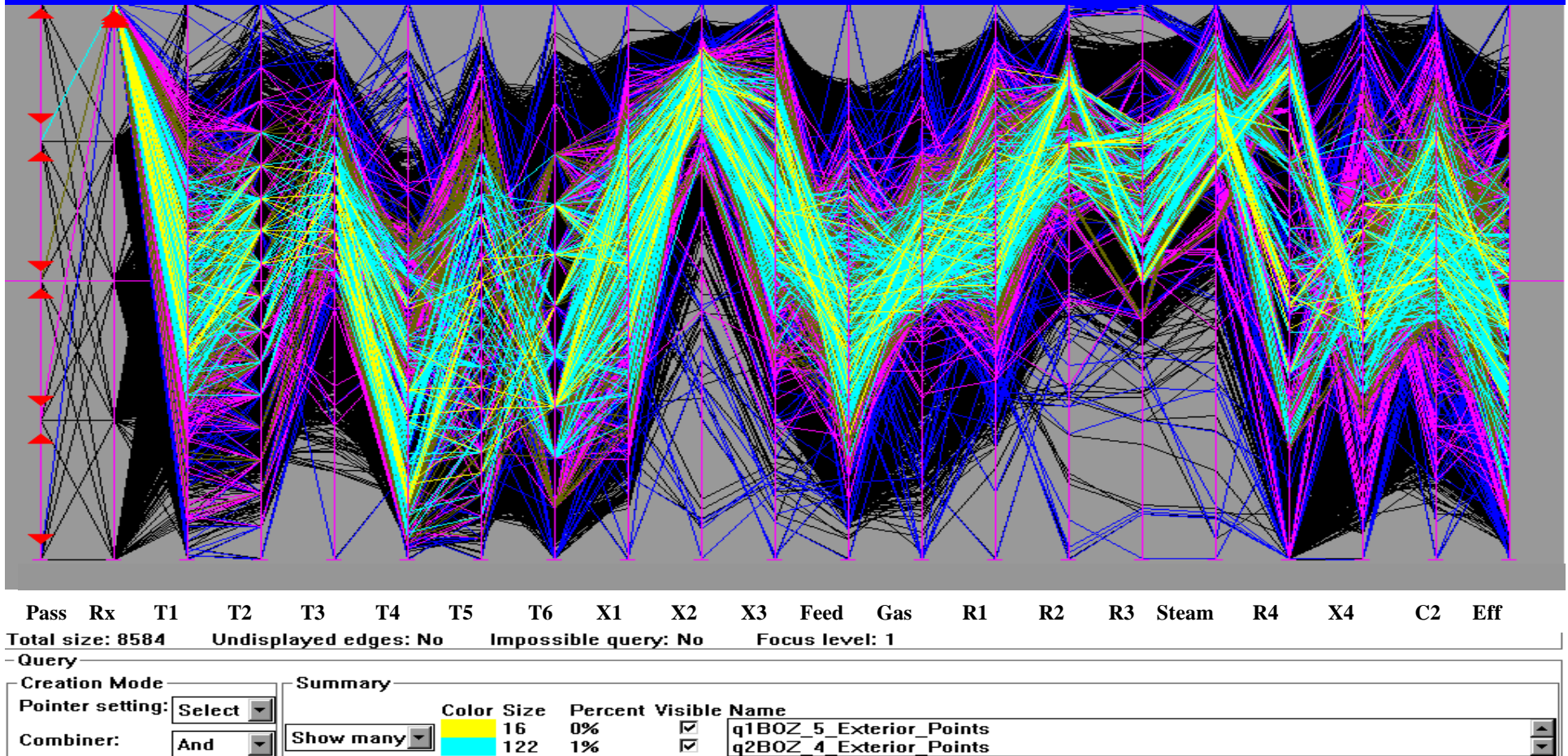
Shows a wide variety of operating practices

High Feed & R1 not beneficial, low Feed & R1 never pay

High T2 never pays

X1 strongly related to all reactor X2's

Conservative Operation Contours



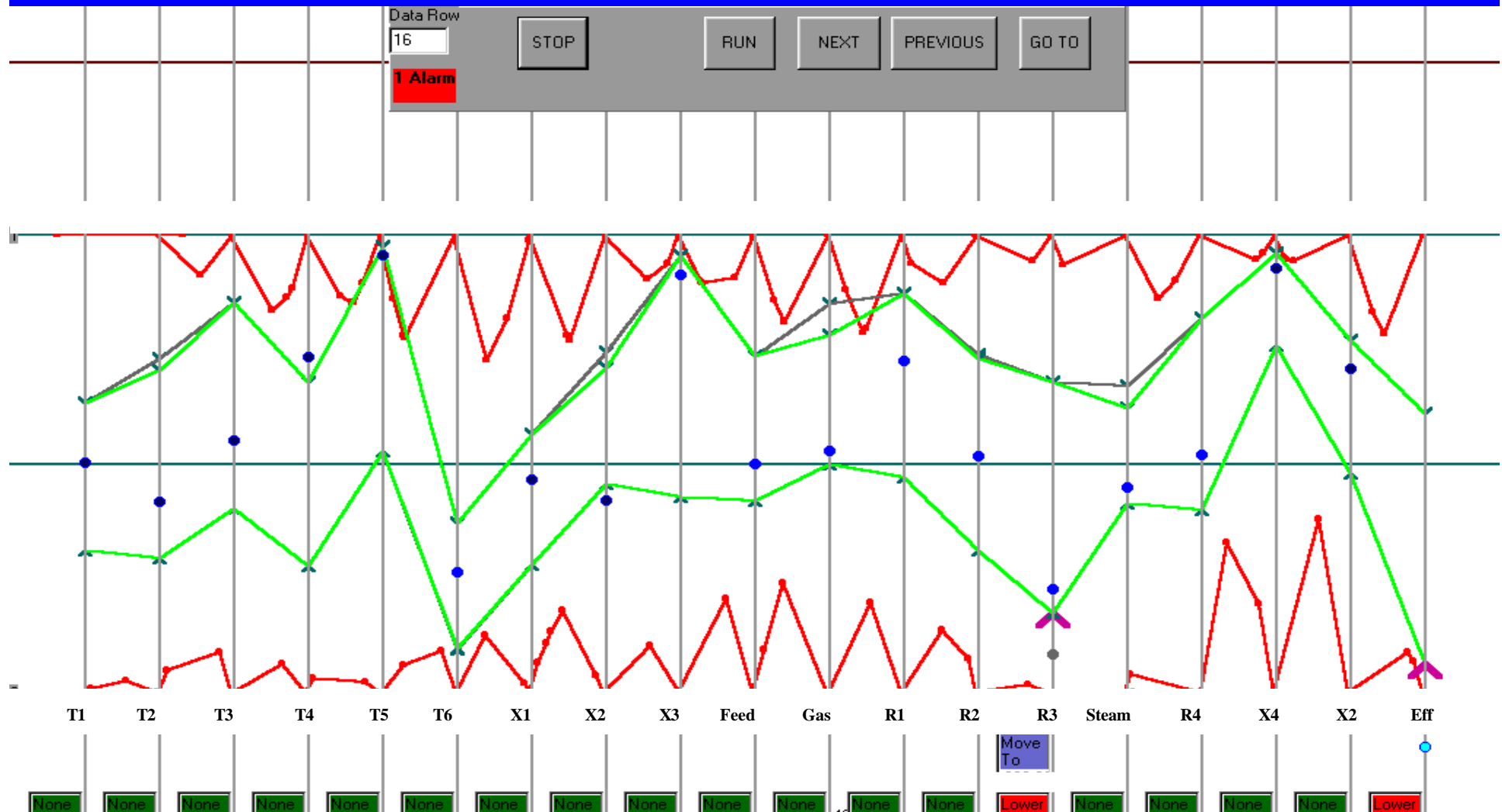
Nested contours for Efficiency $> 68\%$. Most conservative operation would give Eff $\sim 73\%$, most aggressive $\sim 76\%$. Optimisation being added to exploit.

A Best Operating Zone

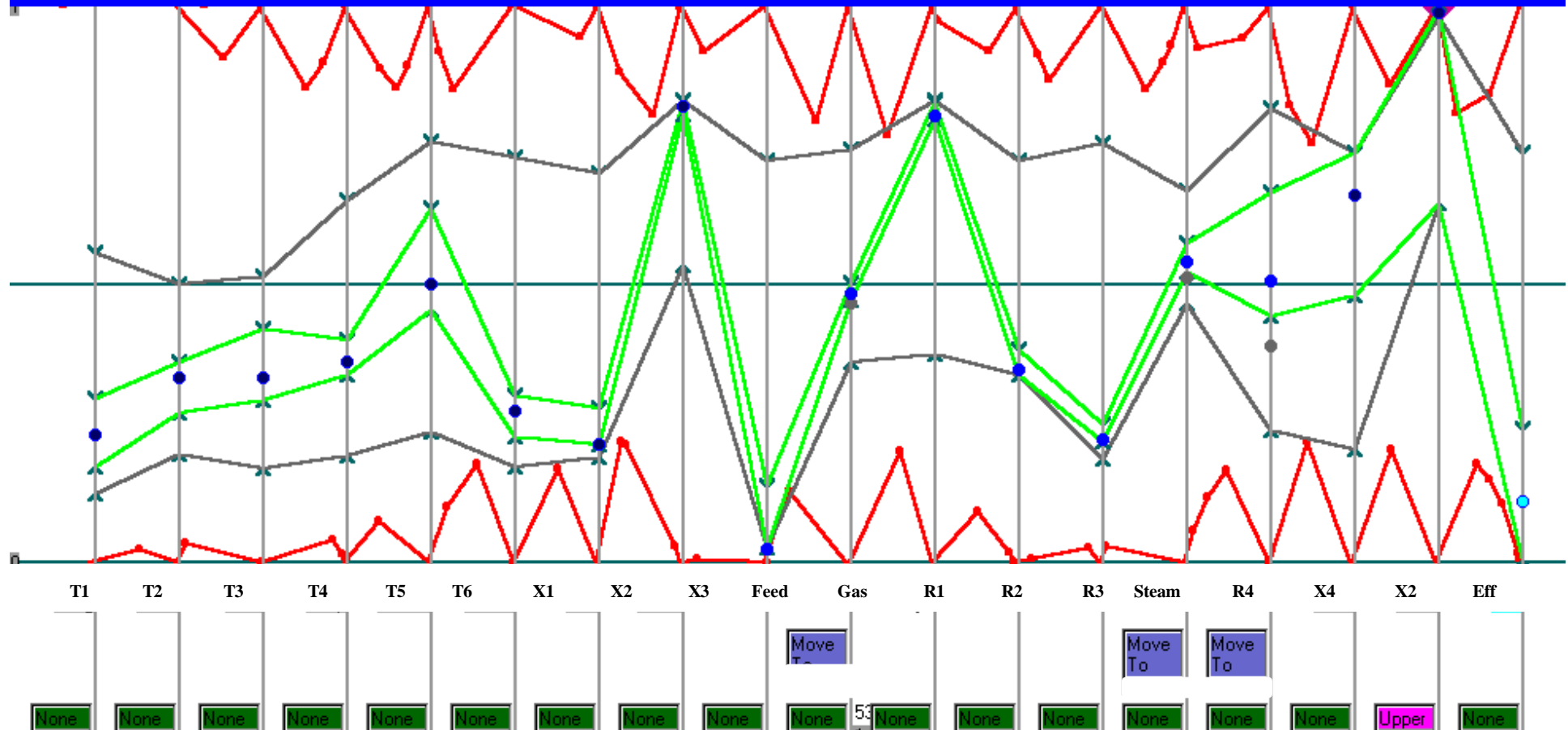
A BOZ is a set of points that are representative of the process capability over a long time span in achieving the objective that the BOZ is to enforce.

“Selectivity” is the fraction of all the points considered that are included in the BOZ. The complement of Selectivity is the fraction of operating time that one or more BOZ violations will be present. If this is too high the operator will ignore the alarms – just like now – and no improvement will result. We suggest Selectivity >85-90% and improvement in a series of steps. This is practical because BOZ definition is so simple.

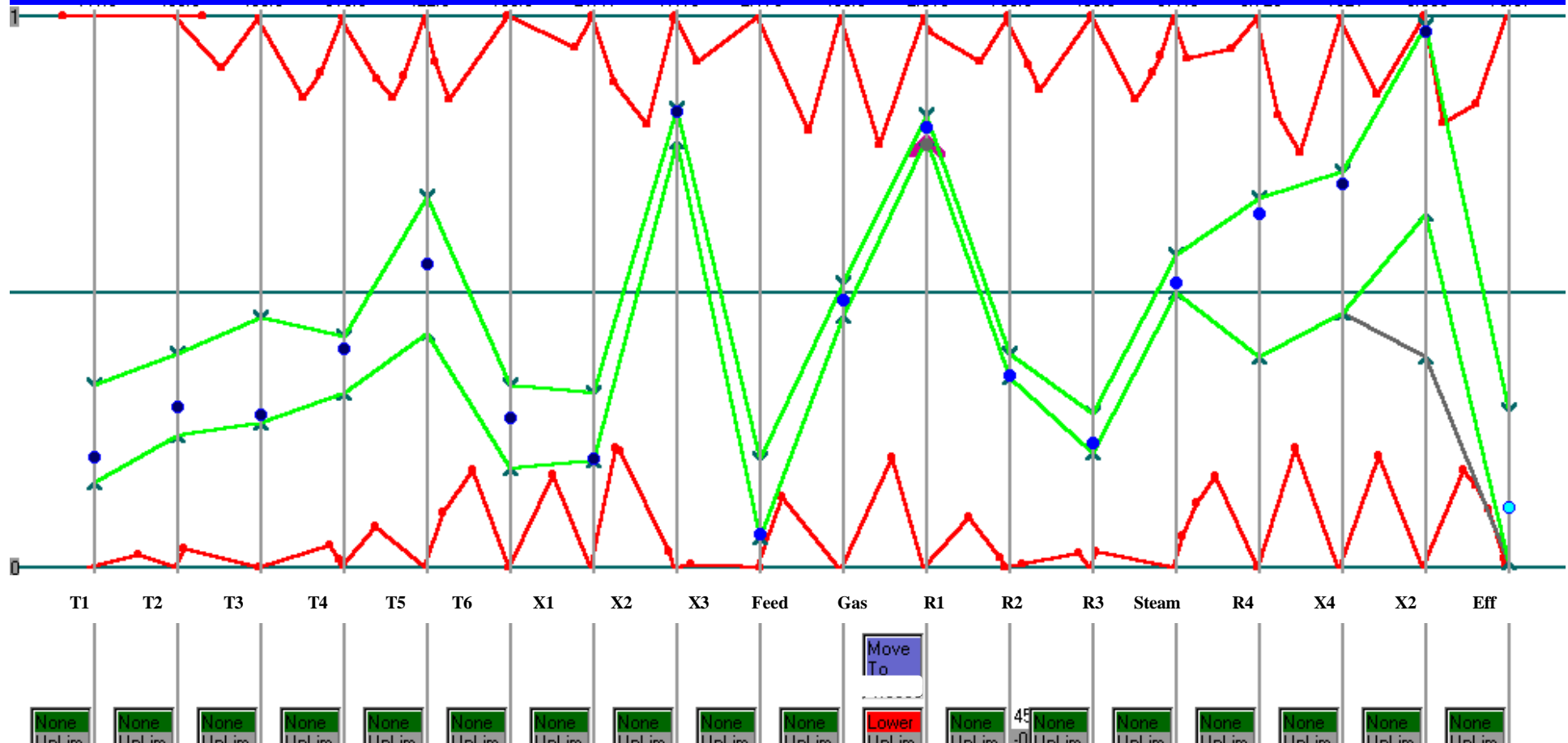
Increase R^2 to correct predicted Eff



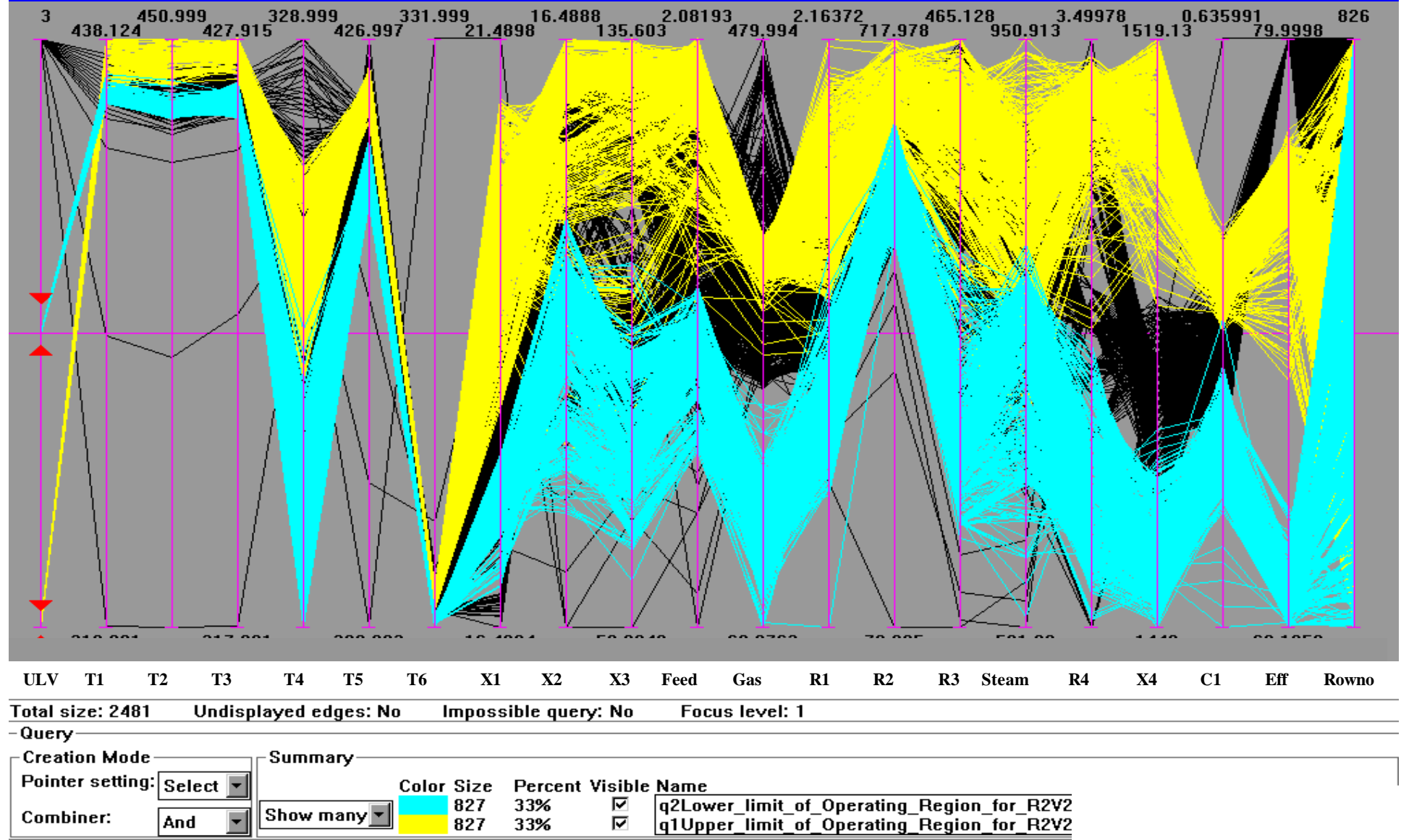
3 moves to clear 1 alarm



Operating at an extreme is hard -
but at least the extreme can now be
seen!



A 'Difficult' Process because no 'set & forget' values for R1, R2, R3, Steam



Alarm Log

Row No	Var ID	Var Value	Limit Type	Alarm Value	Alarm Type	Alarm Prio.	Alarm(s) Cleared
13	LStm	521.199	Upper	521.185	New	W	
14					LStm		
53	KT	59.130	Upper	59.126	New	W	
54	LStm	520.699	Upper	520.689	New	W	KT
55					LStm		
58	Feed	668.392	Lower	668.406	New	W	
59					Feed		
60	BotF	348.495	Lower	348.509	New	W	
60	RfxoT	145.499	Upper	145.493	New	W	
61	RfxinT	98.900	Lower	98.938	New	New	W
61	LouT	260.600	Lower	260.602	New	W	BotF RfxoT
62	KStm	79.900	Upper	79.896	New	W	RfxinT LouT
63					KStm		

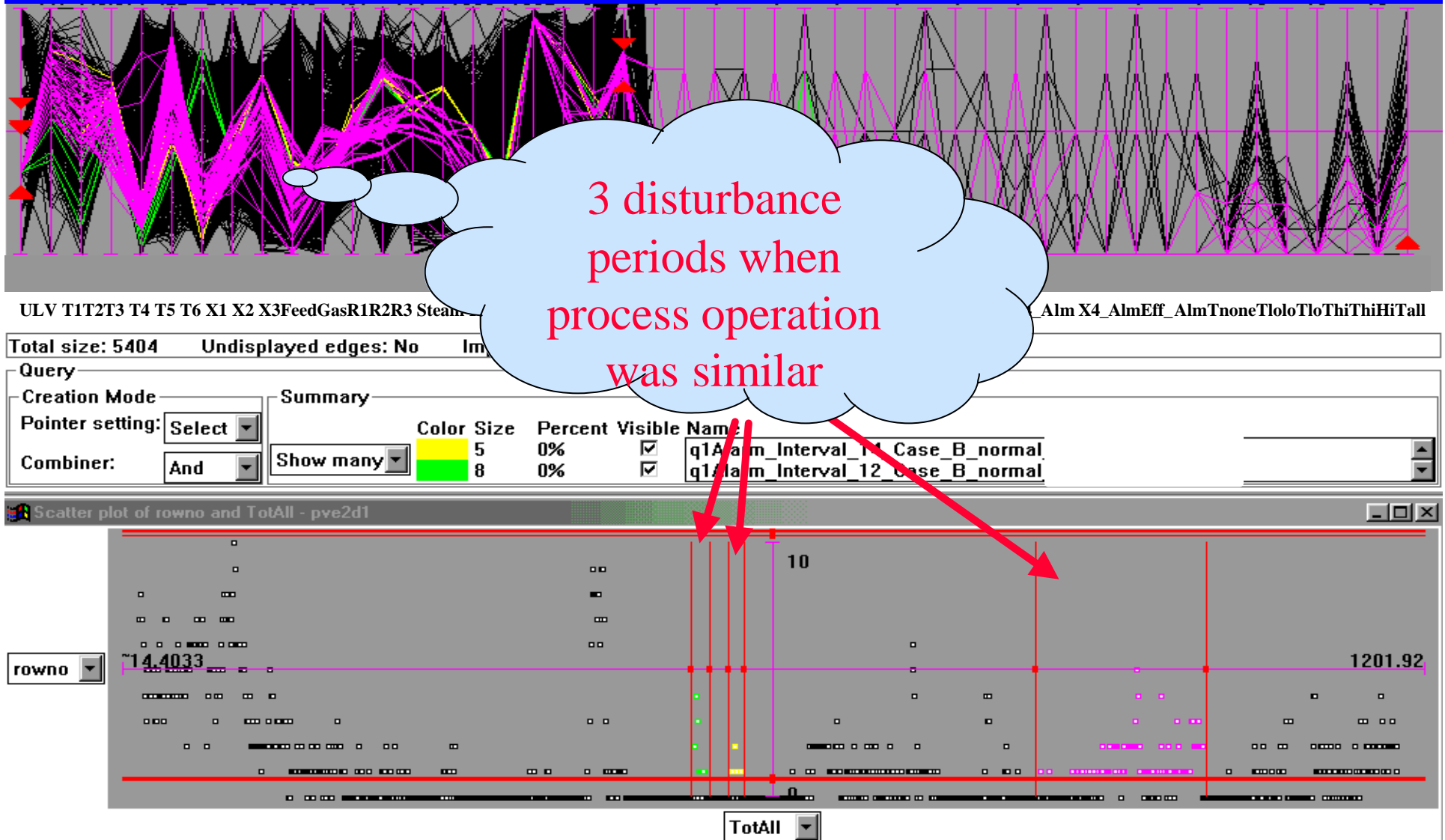
CPM Alarm Log – we originally thought this would be a familiar way to compare CPM and actual alarms. CVE was much more useful

Alarm Log Summary

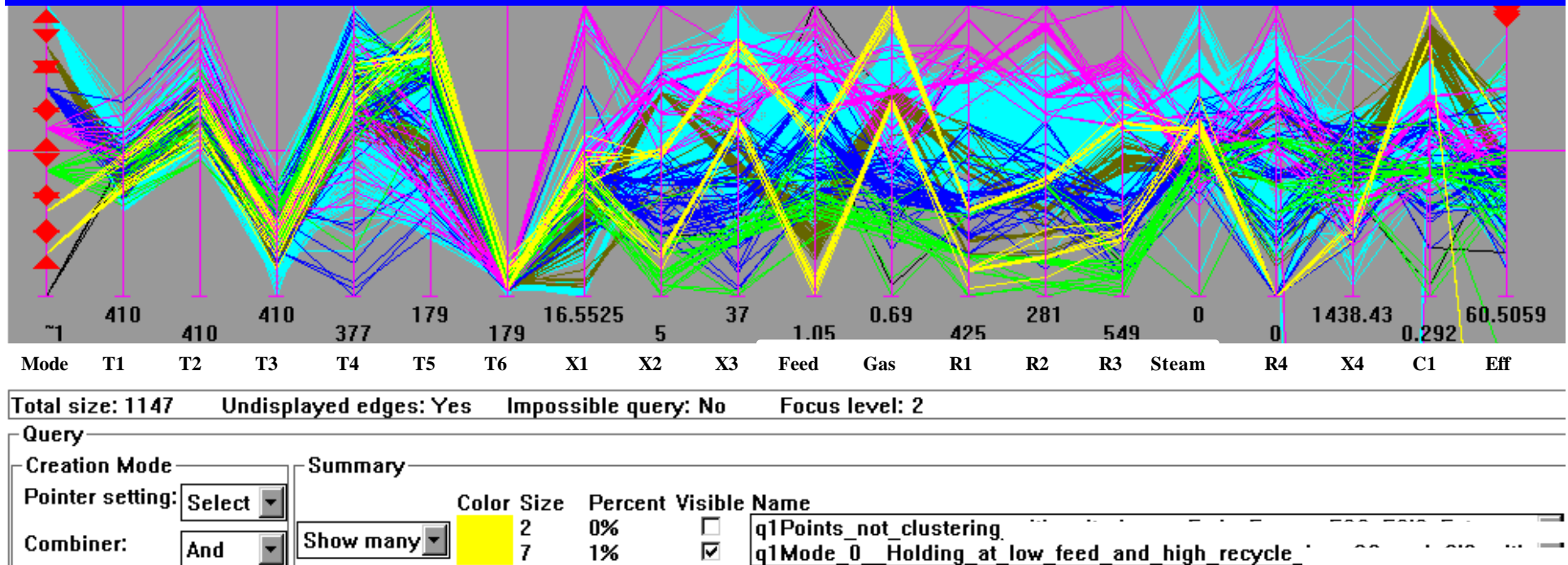
	T1	T2	T3	T4	T5	T6	X1	X2	X3	Feed	Gas	R1	R2	R3	Steam	R4	X4	Eff								
LoLo	7	4	3	0	3	0	0	2	2	0	0	3	0	0	0	0	0	0	0	24	198	144	8	342	32	374
Low	17	37	21	0	0	1	32	1	16	0	3	59	0	4	7	0	0	0	0	841	704	725	842	634	837	629
High	0	0	1	39	16	5	0	4	1	57	0	0	3	2	16	0	0	0	0							
HiHi	0	0	0	0	4	2	1	0	0	0	0	0	0	0	0	1	0	827	0							
All	24	41	25	39	23	8	33	7	19	57	3	62	3	6	23	1	0	827	0	Alarm % of timesteps on						
LoLo%	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	17	15	1	25	1	26
Low%	2	4	2	0	0	0	4	0	2	0	0	7	0	0	1	0	0	0	0							
High%	0	0	0	5	2	1	0	0	0	7	0	0	0	0	2	0	0	0	0							
HiHi%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97	0							
All %	3	5	3	5	3	1	4	1	2	7	0	7	0	1	3	0	0	97	0							

Statistics as used in Alarm Rationalisation from others helped but proved a very slow, tedious and inadequate means to understand a complex multi-variable situation So we reverted to CVE and made enormous steps in understanding and equally enormous time savings

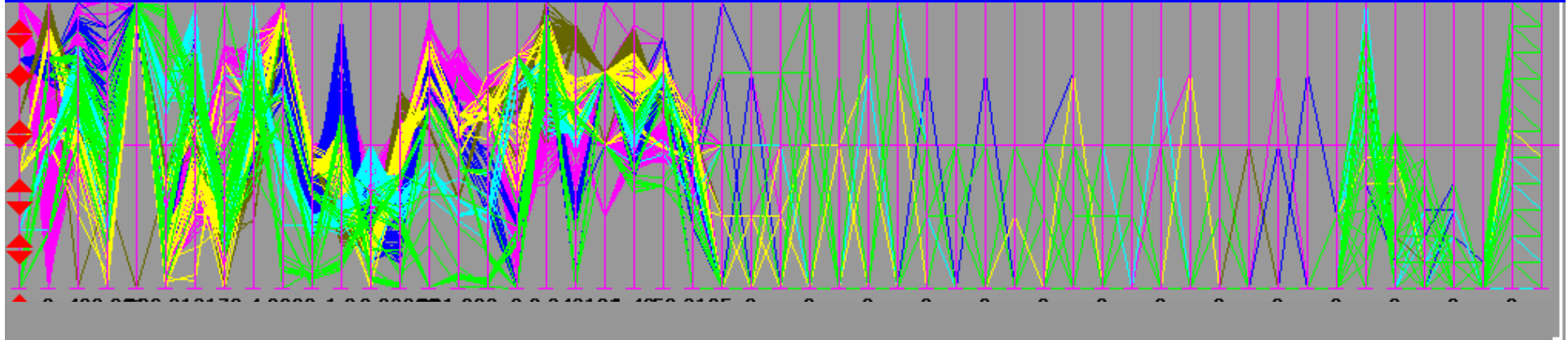
The BIG Picture - Visual Operations Analysis



7 Modes of Operation found in minutes with Clustering



Disturbances Periods by Mode



ULV T1T2T3 T4 T5 T6 X1 X2 X3FeedGasR1R2R3 Steam R4 X4 C1Eff T1T2T3 T4 T5 T6 X1 X2 X3FeedGasR1R2R3 Steam_Al R4_Alm X4_AlmEff_AlmTnoneTloloTloThiThiHiTall

Total size: 927 Undisplayed edges: No Impossible query: No Focus level: 2

Query

Creation Mode

Pointer setting: Select

Combiner: And

Summary

Show many

Color Size

89 612

Percent

10% 66%

Visible

100% 100%

Name

q2High_fresh_feed_and_Low_Recycle_10_pct

q1Normal_Throughput_66_pct

Scatter plot of rowno and tall - pve2d1

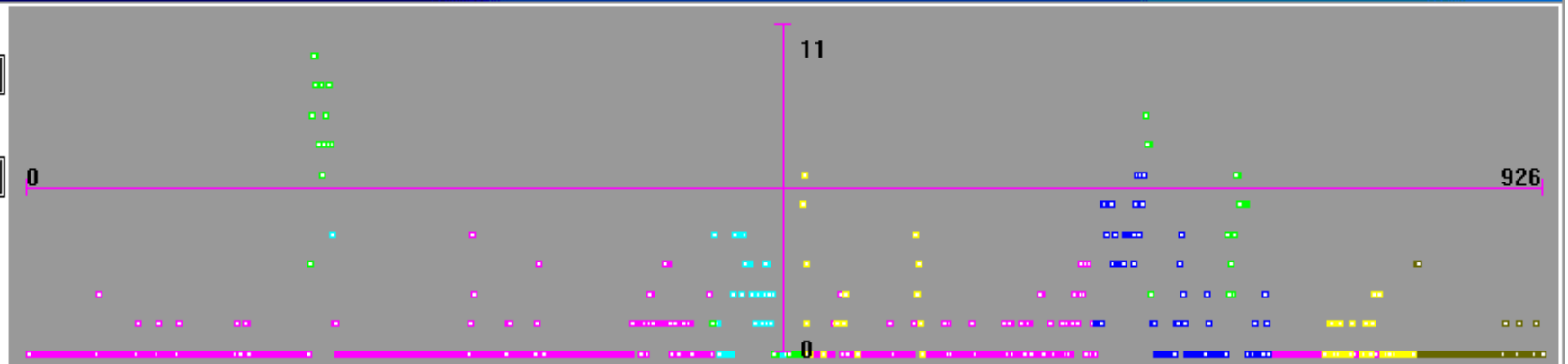
Y Variable

tall

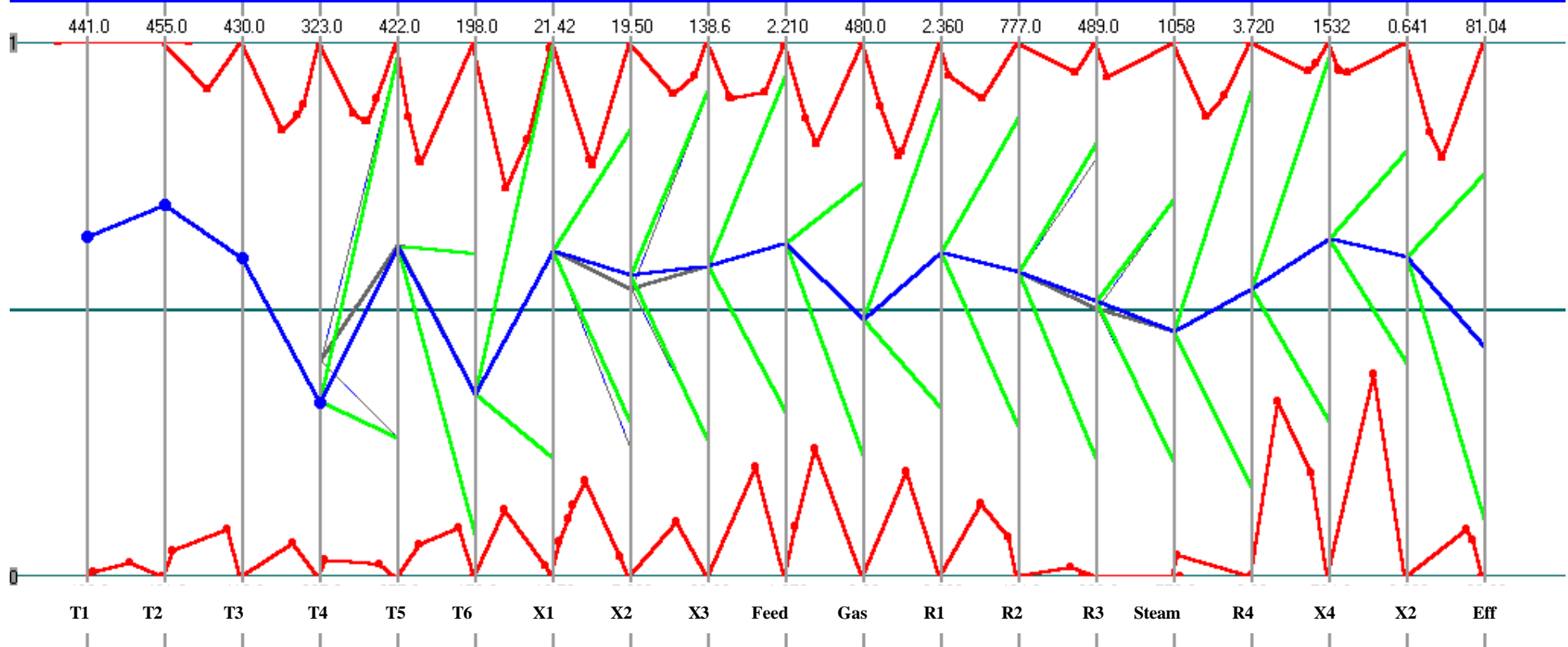
X Variable

rowno

Close



Response Surface



Time available has not permitted much use of response surface analysis in this project

A Brand-New Technology

- Does it do what it claims? YES
- Alarms YES
- Quality Improvement YES
- Operations Improvement YES
- Ease of use YES