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Tevatron Higher Energy Testing

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A cryogenic system upgrade was installed in 1993 to lower the temperature of the Tevatron in order to achieve higher operating energies. Centrifugal cold helium vapor compressors were used to lower the temperature of the two-phase circuit of the Tevatron. A cold compressor (CC) is used at each of the twenty-four satellite refrigerators, allowing each satellite to be individually tuned to the temperature necessary for the magnets.

Initial testing took place in December, 1993 and January, 1994. During that time, we uniformly tuned the Tevatron for 11 psia (3.93 K) cold compressor operation. Fifteen quenches were achieved. All of them were ramp-to-quench from either a 900 GeV ramp or the QBS test ramp. Approximately ten of the quenches appeared to be training quenches. The ultimate ramp-to-quench energy achieved was 998 GeV.

The second major testing sequence took place in July, 1995, just prior to a two month shutdown. Again, the entire Tevatron was tuned for a uniform cold compressor temperature of 11 psia (3.93 K). Two changes were made compared to the 1993/94 testing. First, the helium flow in the magnets was kept constant when pumping down from the nominal 19 psia to 11 psia. During previous testing, the magnet JT valves were kept locked, resulting in considerably higher flows at 11 psia operation.

Second, instead of ramp-to-quench testing, ramping at a lower energy was started and the flattop energy was increased 5 GeV after three successful ramps. These two changes resulted in a lower peak quench energy of 990 GeV. A attempt was made to uniformly tune the cold compressor temperatures down to 8.5 psia to investigate the increase in quench energy. A failure in a turbine at CHL cold box II put an end to the test prior to powering the Tevatron. Uniform operation at 8.5 psia (3.69 K) is not possible steady state due to capacity limits of CHL cold box II. During this test, we were slowly consuming liquid from storage in order to make up the difference.

Previous testing in A sector showed that some magnet strings perform better at 11 psia operation than others perform at 8 psia. Individually tuning the temperature at each of the twenty-four satellites allows us to conserve CHL capacity for magnet strings that exhibit the poorest quench performance. As a result, the goal of the recent testing in October, 1995, was to determine the quench energy of the Tevatron while individually tuning the operating temperature of each satellite system until a lower temperature limit was reached in the quench limiting house.

Twelve shifts of testing was given between October 12 and 17. The test program is given in Appendix 1. Two initial quenches were made with a uniform cold compressor temperature of 11 psia (3.93 K). The Tevatron was then individually tuned to the temperatures given in the table of Appendix 1. These initial temperatures were arrived at using previous quench performance experience and, to a smaller extent, MTF data with

consideration as to its Tevatron lattice location. Lattice location is important since the single-phase temperature varies throughout a half cell. The warmest location is just downstream (with respect to single-phase flow) of a spool piece.

The results of the testing are presented in Table 1, along with the testing in July, 1995. The tune of the satellite for each quench is given in Table 2. This table gives the cold compressor operating pressure (PI11) as well as the upstream (EVUH) and downstream (EVDH) magnet string JT valve positions. Typically, only changes are given in the table. To find a value for a given quench, move up to lower quench numbers until a value is found.

The results are shown graphically in Figure 1. A maximum quench energy of 1010 GeV was achieved. Quenches 21-23 were performed with one satellite at higher temperature in order to guarantee a quench in that house. PDQ was installed in cells that had repeat quenches in order to identify the quenching component. Figure 2 shows the quench performance of the weakest magnets identified in the Tevatron. Locations A48-3, A28-4 and A34-2 were previously identified during A sector testing. The only A sector magnet that is currently limiting the performance of the Tevatron is A48-3, although A28-4 required operation at the lowest practical limit of the cold compressor.

The five weakest magnets identified in the Tevatron are presented in Table 3. They will need to be replaced in order to achieve 1000 GeV operation (1030 GeV quench level) in the Tevatron. The column labeled Rank represents the rank of the MTF Saver ramp quench limit for installed magnets in the Tevatron. Note that none of the magnets are in the top twenty worst magnets.

Table 3 Identified Weakest Tevatron Magnets

Location	CC Temp.	Quench Energy	Magnet	MTF Saver Ramp	MTF Ramp to Quench	Rank Saver Ramp	Lattice Thermal Location
	K	GeV	#	amps	amps		
E24-2	3.52	1010	TC0504	4233	4389	80	good
C42-4	3.93	990	TB0214	4144	4374	21	medium
D27-2	3.84	1010	TB0208	4175	4309	37	bad
B18-4	3.84	1010	TC1052	4236	4421	86	medium
A48-3	3.93	1000	TC1135	4235	4505	84	bad

The column labeled Lattice represents the magnets thermal location within the half cell. A bad location is just downstream (with respect to single-phase flow) of a spool piece. A value of medium and good represents the middle and end of the half cell, respectively.

Conclusions

Quench tests were performed in the Tevatron to determine the quench energy of the Tevatron while individually tuning the operating temperature of each satellite system until a lower temperature limit was reached in the quench limiting house. The lowest practical operating temperature was reached in five satellites. The quenching magnet was identified in each of these locations. The magnets will need to be replaced in order to proceed to higher energy, with the goal being 1000 GeV operation (1030 GeV quench energy) for Collider Run II.

Power Test Quench Log July 1995

#	Date	Time	Cell	E GeV	I amps	2 σ psia	2 σ K	Detect cycle sec	rate GeV/s	flat top sec	Cycle Location	Comment
0				930	4129	18.5	4.476					
1	Jul 27	13:03	B32U	961	4267	11.0	3.928	7.0	200	28	23 on ramp up	very slow quench
2	Jul 27	16:08	E22U	980	4355	11.0	3.928	2.0	200	28	23 at flat top	on 3rd ramp
3	Jul 27	20:01	F42U	144	640	11.0	3.928	2.0	200	28	23	HFU problem
4	Jul 27	22:55	C42L	990	4390	11.0	3.928	2.0	200	28	23 10 s into FT	
5	Jul 28	00:44	F42U	144	640	11.0	3.928	2.0	200	28	23 10 s into FT	HFU problem
6	Jul 28	02:37	C42L	990	4390	11.0	3.928	2.0	200	28	23 10 s into FT	
7	Jul 28	09:00	C42L C42-4	990	4390	11.0	3.928		200	28	23 10 s into FT	TB214
8	Jul 28	12:13	E24U	990	4390	11.0	3.928		200	28	23 20 s into FT	C4 at 8 psia
9	Oct 12	18:38	E24U	980		11.0	3.928	2.5	200	28	23 20 s into FT	
10	Oct 12	21:42	C42L	985		11.0	3.928	1.5	200	28	23 22 s into FT	
11	Oct 13	03:49	C15L	992		11.0	3.928	2.5	200	28	23 on ramp up	after three 995 GeV ramps
12	Oct 13	09:16	D19U	995		11.0	3.928	2.5	200	28	23 on ramp up	after three 995 GeV ramps
13	Oct 13	15:36	D28L	1000		11.0	3.928	1.5	200	28	23 10 s into FT	on way up to 1000 GeV
14	Oct 13	18:25	B19U	1000		11.0	3.928	2.5	200	28	23 end FT	
15	Oct 13	21:26	E24U	1005		8.0	3.635	2.5	200	28	23 10 s into FT	

Table 1 (cont)

Power Test Quench Log

July 1995

[illegible]

Power Test Quench Log

July and October 1995

[illegible]

Table 2 (cont)

Power Test Quench Log

July and October 1995

[illegible]

Power Test Quench Log

July and October 1995

[illegible]

Figure 1

Tevatron Quench Tests July and October, 1995

Figure 2

Tevatron Quench Tests Identified Weak Magnets

Appendix 1 Test Procedure

Tevatron higher energy power testing

Goals: Determine the quench energy of the Tevatron while individually tuning the operating temperature of each satellite system until a lower temperature limit is reached in the quench limiting house.

Secondary goals:

Correlate results with MTF quench data, coupled with the magnet location in the Tevatron lattice.

Uses: Tevatron higher energy operation

Hardware requirements:

Three compressor operation of cold box II
Cold compressor operation

Controls requirements:

none

Operations requirements:

Dedicated study

Procedure:

- 1) Uniformly tune the Tevatron for 11 psia operation for two baseline quenches.
- 2) Obtain two baseline quenches using the following procedure.
 - A) Using a standard collider ramp (file 16), start a 900 GeV ramp.
 - B) Ramp three times.
 - C) Install a 950 GeV ramp.
 - D) Ramp three times.
 - E) Install a 975 GeV ramp.
 - F) Ramp three times.
 - G) Increase the flattop energy by 5 GeV.
 - H) Ramp three times.
 - I) Repeat G and H until quench occurs.
 - J) Save QPM circular buffer.
- 3) Tune the Tevatron temperatures according to the attached sheet.
- 4) Obtain a quench using the procedure in 2.
- 5) Lower the house that quenched by 1 psia.
- 6) Repeat 4 and 5 as time permits or until a lower limit (8 psia) is reached in the quench limiting house.

Initial Temperature Tune for Tevatron Power Testing

12-Oct-95

2 ϕ P psia	2 ϕ T K	EVUH min %	EVDH min %	status	cell	device	comment	others
A1	11.0	3.928	53					A17-5 A18-4
A2	8.0	3.635	51	known	A28-4	TB0317	from A sector tests	A21-2 A28-2
A3	10.0	3.837	52	known	A34-2	TC0412	from A sector tests	A29-5 A32-2 A37-3 A33-2
A4	8.0	3.635	36	known	A48-3	TC1135	from A sector tests (next to TSH)	A39-3
B1	11.0	3.928	59					B17-4 B11-2
B2	10.0	3.837	48	suspect	B28-2	TC1073	location	B27-2 B25-2
B3	11.0	3.928	53					B33-2
B4	10.0	3.837	51	suspect	B44-5	TB0295	location	B42-5 B47-4 B46-5 B45-2
C1	11.0	3.928	50					C13-5 C14-3 C13-3
C2	11.0	3.928	27					C21-5
C3	11.0	3.928	49					C36-3 C33-4 C35-3
C4	8.0	3.635	47	known	C42-4	TB0214	from Tev testing	C43-3 C39-3
D1	11.0	3.928	54					D27-2 D25-2 D21-2 D26-5
D2	11.0	3.928	52					
D3	11.0	3.928	54					
D4	11.0	3.928	50					D46-2 D46-5
E1	11.0	3.928	52					
E2	8.0	3.635	37	known	E24U		from Tev testing	E37-2 E38-4
E3	11.0	3.928	52					
E4	11.0	3.928	50					
F1	11.0	3.928	53					F16-3 F15-4
F2	11.0	3.928	62					
F3	11.0	3.928	49					F37-2 F29-5 F36-5 F38-3
F4	11.0	3.928	52					F39-3

Italic represents weak magnet in a bad location.