Fermilab Main Injector
Conceptual Design Report, Revision 3.1

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1. INTRODUCTION AND SUMMARY

This report contains a description of the design and cost estimate of a new 150 GeV accelerator, designated the Fermilab Main Injector (FMI). The construction of this accelerator will simultaneously result in significant enhancements to both the Fermilab collider and fixed target programs. The FMI is to be located south of the Antiproton Source and tangent to the Tevatron ring at the F0 straight section as shown in Figure 1-1. The FMI will perform all duties currently required of the existing Main Ring. Thus, operation of the Main Ring will cease following commissioning of the FMI, with a concurrent reduction in background rates as seen in the colliding beam detectors. The performance of the FMI, as measured in terms of protons per second delivered to the antiproton production target or total protons delivered to the Tevatron, is expected to exceed that of the Main Ring by a factor of two-to-three. In addition the FMI will provide high duty factor 120 GeV beam to the experimental areas during collider operation, a capability which does not presently exist in the Main Ring.

The location, operating energy, and mode of construction of the FMI are chosen to minimize operational impact on Fermilab's ongoing High Energy Physics (HEP) program. The area in which the FMI is to be situated is devoid of any underground utilities which might be disturbed during construction, while the separation between the FMI and Tevatron is sufficient to allow construction concurrent with Tevatron operations. The energy capability of the FMI is chosen to match the antiproton production and Tevatron injection energies presently used in the Fermilab complex. The FMI will be built from newly constructed dipole magnets allowing a large portion of the installation process to proceed independent of Tevatron operations. The use of newly designed dipoles is also desirable from the standpoint of enhanced performance and reliability, and results in a reduction of the operating costs by 33% relative to what would be obtained by recycling existing Main Ring magnets.

The Total Project Cost (TPC) of the FMI is estimated to be $242,400,000 including a Total Estimated Construction Cost (TECC) of $213,300,000 and $29,100,000 in associated R&D, pre-operating, capital equipment, conceptual design, and spares costs. Included within the scope of the project are all technical and civil construction components associated with the ring itself, with beamlines needed to tie the ring into the existing accelerator complex, and with modifications to the Tevatron and switchyard required to accommodate the relocated injections. The project involves the construction of 15,000 ft of tunnel enclosures, 11 service buildings, and a new 345 kV substation. The FMI ring and all beamline interconnections to existing facilities are shown schematically in Figure 1-2. It is proposed to complete construction over a five year period starting on March 1, 1992. Design of civil construction will be done by an outside Architectural Engineering (AE) firm with support from the Fermilab Engineering Support Section. Design of technical components will

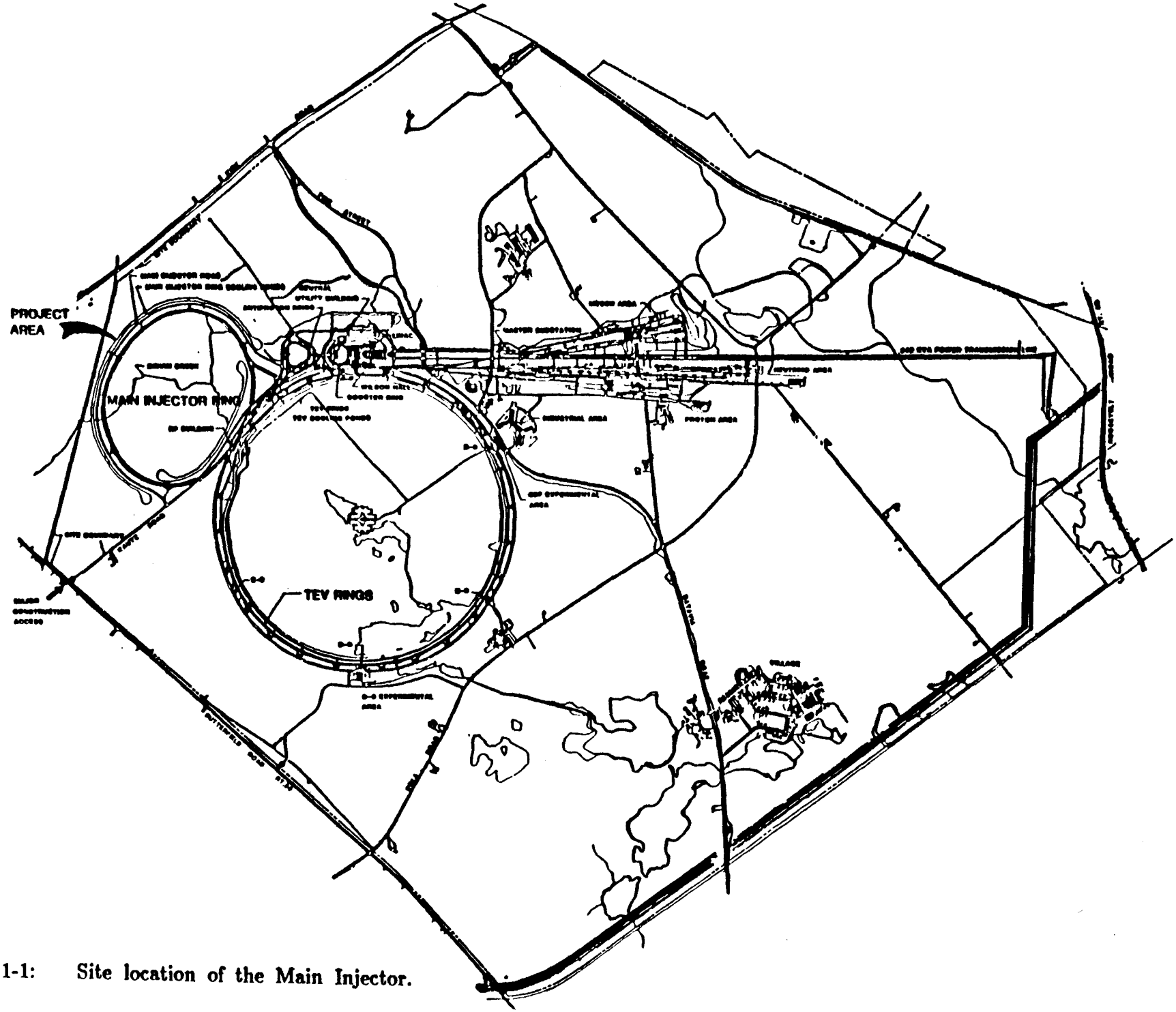


Figure 1-1: Site location of the Main Injector.

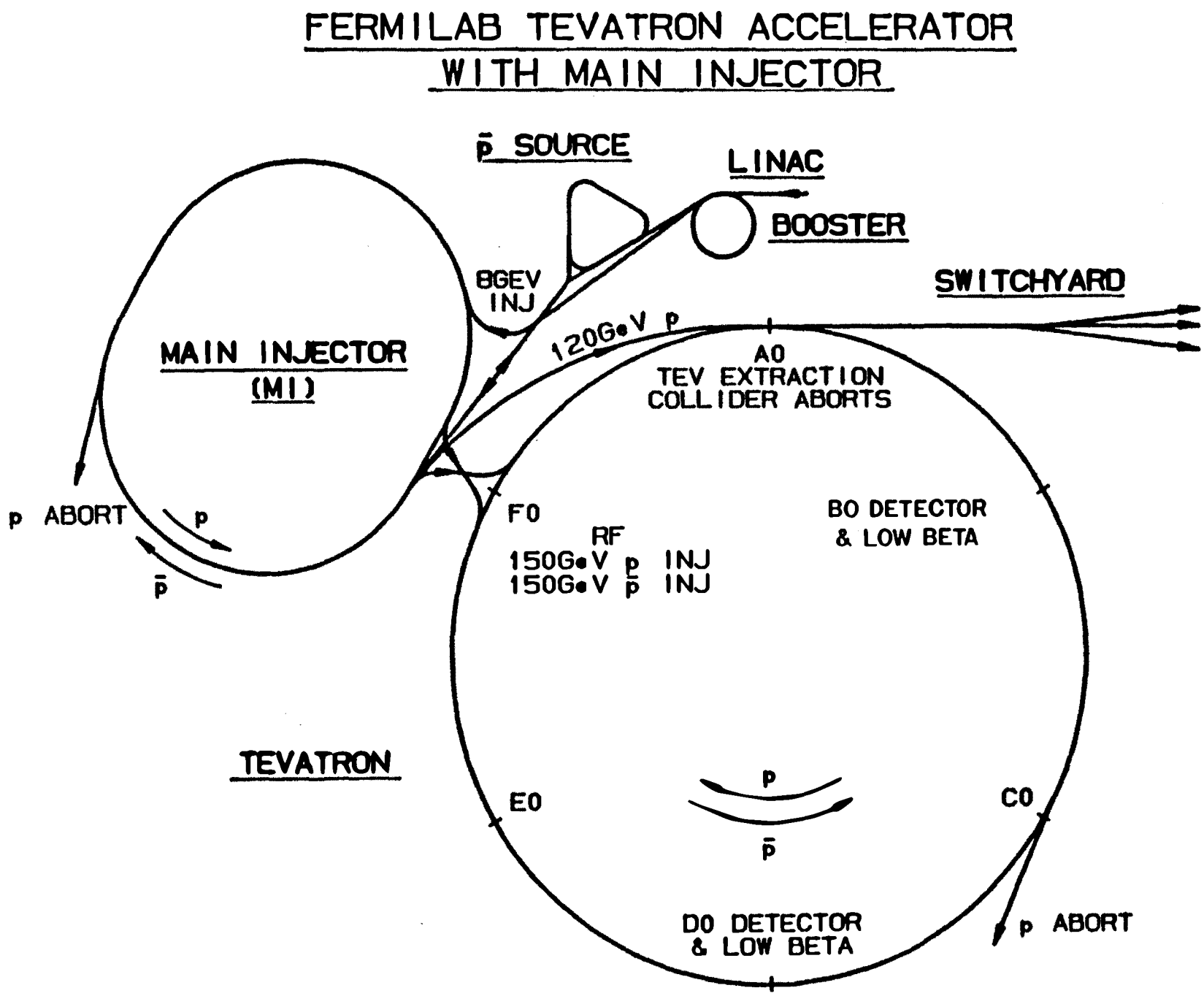


Figure 1-2: Schematic view of Main Injector connections to Booster, Antiproton Source, Tevatron, and Switchyard.

be done by Accelerator Division and Technical Support Section personnel. It is anticipated that construction and operation of the new FMI will not require any expansion of the Fermilab permanent staff.

1.1 Role in the Fermilab III Program

The FMI is the centerpiece of Fermilab's initiative for the 1990s, known as Fermilab III. The goal of Fermilab III is to discover and illuminate the properties of the top quark, the last unobserved fundamental building block of matter according to our current understanding of nature, to provide a factor of 2 increase in the mass scales characterizing possible extensions to the Standard Model, and to support new initiatives in neutral kaon physics and neutrino oscillations. In order to attain these goals Fermilab is planning to attain by mid-decade a luminosity in excess of 5×10^{31} $cm^{-2}sec^{-1}$ in the Tevatron $\bar{p}$-p collider, supported by a new 150 GeV accelerator, the FMI.

Several projects already underway will result in a factor of 6 improvement in luminosity over the current performance of 1.6×10^{30} $cm^{-2}sec^{-1}$ by 1993. These include upgrades to the Antiproton Source to improve the yield by a factor of 3, development of new low-β systems which will allow the implementation of a second high luminosity interaction region, development of separators to allow multibunch operation, and the installation of cold compressors to raise the Tevatron energy. On October 1, 1989 work was initiated on raising the Linac energy from 200 MeV to 400 MeV for the purpose of increasing the antiproton production rate by 75% and reducing proton beam emittances by 40%. As a result of these enhancements it is expected that the luminosity of the collider will gradually increase to $1\times10^{31}cm^{-2}sec^{-1}$ by 1993. It is also anticipated that these developments will increase the number of protons delivered from the Tevatron for fixed target physics up to 3×10^{13} per minute.

Further improvements to performance require the construction of the FMI. The present bottleneck in the production of antiprotons and in the delivery of intense beams to the Tevatron is the Main Ring. The Main Ring is not capable of accelerating the quantity of protons which can be provided at injection by the 8 GeV Booster. This is for the simple reason that the aperture of the Main Ring (12π mm-mr as measured in normalized units at 8.9 GeV/c) is about half the size of the Booster aperture (20π mm-mr). As a result the Booster is run at about two-thirds of its capability during normal operations. Additionally, the Main Ring is not capable of accelerating antiprotons delivered from large stacks in the Antiproton Source due to the larger emittances associated with larger stacks. As a result the Source is limited to stacks containing 6×10^{11} antiprotons (about two-thirds of its present capability) during collider operations. The restricted aperture in the Main Ring is due to perturbations

to the ring which have been required for the integration of overpasses and new injection and extraction systems related to operations with antiprotons. With the 400 MeV Linac upgrade the Booster aperture at injection will be increased to 30π mm-mr due to increased adiabatic damping within the new linac, and the ability to produce larger antiproton stacks will be increased. The mismatches between Booster/Antiproton Source and Main Ring capabilities will become even more acute. Only with the construction of the FMI will these mismatches be removed, and the full benefit to the collider and fixed target programs of the upgrade projects currently underway be realized.

The construction of the FMI will also provide beams of up to 3×10^{13} protons at 120 GeV to the experimental areas during collider runs. Such beams are envisioned as being used for detector development, for the debugging and shakedown of fixed target experiments prior to commencement of 1 TeV fixed target runs, and for supporting certain specialized rare K decay and neutrino experiments which can benefit from the high average intensity deliverable from the FMI. The Main Ring as presently configured does not support a slow spill, nor is it felt that implementation of a high intensity slow spill in the existing ring would be feasible in light of the small machine aperture and the need to minimize backgrounds in the collider experiments.

Specifically, benefits expected from the construction of the FMI include:

1. An increase in the number of protons targeted for $\bar{p}$ production from 5.0×10^{15}/hour (following the Linac upgrade) to 1.2×10^{16}/hour.

2. An increase in the total number of protons which can be delivered to the Tevatron to 6×10^{13}.

3. The ability to accelerate efficiently antiprotons originating in stacks containing 2×10^{12} $\bar{p}$ for injection into the Tevatron collider.

4. The ability to produce proton bunches containing up to 3×10^{11} protons for injection into the Tevatron collider.

5. The reduction of backgrounds and deadtime at the CDF and DO detectors through removal of the Main Ring from the Tevatron enclosure.

6. Provision for slow extracted beams at 120 GeV year around and potential development of very high intensity, high duty factor ($\geq1\times10^{13}$ protons/sec at 120 GeV with 34% duty factor) beams for use in high sensitivity K decay and neutrino experiments.

It is expected that with the construction of the FMI and the completion of planned improvements to the Antiproton Source the antiproton production rate will exceed 1×10^{11} $\bar{p}$/hour, and that a luminosity of 5×10^{31} $cm^{-2}sec^{-1}$ will be supportable in the existing collider.

1.2 Performance

The FMI parameter list is given in Table 1-1. It is anticipated that the FMI will perform at a significantly higher level than the existing Main Ring as measured either in terms of protons delivered per cycle, protons delivered per second, or transmission efficiency. For the most part expected improvements in performance are directly related to the optics of the ring. The FMI ring lies in a plane with stronger focussing per unit length than the Main Ring. This means that the maximum betas are half as big and the maximum (horizontal) dispersion a third as big as in the Main Ring, while vertical dispersion is nonexistent. As a result physical beam sizes associated with given transverse and longitudinal emittances are significantly reduced compared to the Main Ring. The elimination of dispersion in the rf regions, raising the level of the injection field, elimination of sagitta, and improved field quality in the dipoles will all have a beneficial impact on beam dynamics. The construction of new, mechanically simpler magnets is expected to yield a highly reliable machine.

The FMI is seven times the circumference of the Booster and slightly more than half the circumference of the existing Main Ring and Tevatron. Six Booster cycles will be required to fill the FMI and two FMI cycles to fill the Tevatron. The FMI is designed to have a transverse admittance of 40π mm-mr (both planes, normalized at 8.9 GeV/c). This is 30% larger than the expected Booster aperture following the 400 MeV Linac upgrade, and a factor of 3 larger than that of the existing Main Ring. It is expected that the Linac upgrade will yield a beam intensity out of the Booster of $5\text{-}7 \times 10^{12}$ protons per batch with a $20\text{-}30\pi$ mm-mr transverse and a 0.4 eV-sec longitudinal emittance. (All emittances in this report are quoted as 95% normalized values.) A single Booster batch needs to be accelerated for antiproton production while six such batches are required to fill the FMI. The FMI should be capable of accepting and accelerating these protons without significant beam loss or degradation of beam quality. Yields out of the FMI for a full ring are expected to lie in the range $3\text{-}4 \times 10^{13}$ protons ($6\text{-}8 \times 10^{13}$ delivered to the Tevatron.) By way of contrast the existing Main Ring is capable of accelerating 1.8×10^{13} protons in 12 batches for delivery to the Tevatron.

Table 1-1: Main Injector Parameter List

Circumference	3319.419	meters
Injection Momentum	8.9	GeV/c
Peak Momentum	150	GeV/c
Minimum Cycle Time (@120 GeV)	1.5	sec
Number of Protons	3×10^{13}	
Harmonic Number (@53 MHz)	588	
Horizontal Tune	26.4	
Vertical Tune	25.4	
Transition Gamma	20.4	
Natural Chromaticity (H)	-33.6	
Natural Chromaticity (V)	-33.9	
Number of Bunches	498	
Protons/bunch	6×10^{10}	
Transverse Emittance (Normalized)	20π	mm-mr
Longitudinal Emittance	0.4	eV-sec
Transverse Admittance (at 8.9 GeV)	40π	mm-mr
Longitudinal Admittance	0.5	eV-sec
β_{max}	57	meters
Maximum Dispersion	2.0	meters
Number of Straight Sections	8	
Length of Standard Cell	34.6	meters
Phase Advance per Cell	90	degrees
RF Frequency (Injection)	52.8	MHz
RF Frequency (Extraction)	53.1	MHz
RF Voltage	4	MV
Number of Dipoles	216/128	
Dipole Lengths	6.1/4.1	meters
Dipole Field (@150 GeV)	17.2	kGauss
Dipole Field (@8.9 GeV)	1.0	kGauss
Number of Quadrupoles	128/32/48	
Quadrupole Lengths	2.1/2.5/2.9	
Quadrupole Gradient	196	kG/m
Number of Quadrupole Busses	2	

The power supply and magnet system is designed to allow a significant increase in the number of 120 GeV acceleration cycles which can be run each hour for antiproton production, as well as to allow a 120 GeV slow spill with a 35% duty factor. The cycle time at 120 GeV can be as low as 1.5 seconds. This is believed to represent the maximum rate at which the Antiproton Source might ultimately stack antiprotons and is to be compared to the current Main Ring capability of 2.6 seconds. The dipole magnets to be used are designed with twice the total cross section of copper and half as many turns as existing Main Ring dipoles. This is done to keep the total power dissipated in the dipoles during antiproton production at roughly the same level as in present operations while keeping the number of power supplies and service buildings low.

1.3 Operational Modes

At least four distinct roles for the FMI have been identified along with four corresponding acceleration cycles. These are listed in Table 1-2. More detailed description of the acceleration cycles and power supply requirements are given in Section 2 of this report.

1) In the antiproton production mode a single Booster batch containing $5x10^{12}$ protons is injected into the FMI at 8.9 GeV/c. These protons are accelerated to 120 GeV and extracted in a single turn for delivery to the antiproton production target. As mentioned earlier, it is anticipated that with this flux of protons onto the target and expected improvements in the Antiproton Source the antiproton production rate will exceed $1x10^{11}$/hour.

Table 1-2: Main Injector Operational Modes

	Operational Mode	Energy	Cycle	Flattop	Protons
1)	Antiproton Production	120 GeV	1.5 sec	0.04 sec	$5x10^{12}$
2)	Fixed Target Injection	150	2.4	0.25	$3x10^{12}$
3)	Collider Injection	150	4.0	1.45	$5x10^{12}$
4a)	High Intensity Slow Spill	120	2.9	1.0	$3x10^{13}$
4b)	High Intensity Fast Spill	120	1.9	0.04	$3x10^{13}$

2) For fixed target injection the FMI is filled with six Booster batches each containing $5x10^{12}$ protons at 8.9 GeV/c. Since the Booster cycles at 15 Hz, 0.4 seconds are required to fill the FMI. The beam is accelerated to 150 GeV, cogged, and extracted in a single turn for delivery to the Tevatron. The FMI is capable of cycling to 150 GeV every 2.4 seconds for short periods of time. Two FMI cycles are required to fill the Tevatron at 150 GeV at one minute intervals.

3) The FMI operates on a 4 second, 150 GeV cycle for delivery of beam to the Tevatron for collider operations. The acceleration cycle and beam manipulations are the same for both protons and antiprotons. A 1.45 second flattop is required for bunch coalescing and cogging of the beams prior to injection into the Tevatron. Under the currently envisioned filling scenario a maximum of 15 cycles of the FMI are required to load the Tevatron with protons and antiprotons. Assuming a one minute Antiproton Source cycle time, this results in a 10 minute collider fill time. It is anticipated that the collider will require filling approximately every 20 hours.

4) A much higher intensity, high duty factor (34%) beam can be delivered at 120 GeV with a 2.9 second cycle time. The average proton current delivered is about 2 μA (3×10^{13} protons/2.9 seconds). Running in this mode does not put any peak power demands on the power supply system beyond those imposed by the antiproton production cycle, but it does expend 67% more average power. This cycle can also be used to provide test beams to the experimental areas during collider running. In this instance it is likely that a much lower cycle rate, accompanied by a much lower average power, would satisfy experimenters' needs. Additionally, a high intensity, low duty factor beam can be delivered at 120 GeV with a 1.9 second cycle time for the production of high flux neutrino beams.

Combinations of the above operational modes are also possible. One such example is simultaneous operation for antiproton production and high intensity slow spill. One might load the FMI with six Booster batches containing 3×10^{13} protons, accelerate to 120 GeV, fast extract one batch to the antiproton production target, and slow extract the remainder of the beam over a second. This would produce slightly more than half the antiproton flux into the Source and 83% of the average intensity of the dedicated scenarios listed in Table 1-2.

2. THE FERMILAB MAIN INJECTOR

The FMI is a 150 GeV accelerator with a circumference 28/53 times that of the existing Main Ring. The primary design goals are to increase the admittance to 40π mm-mrad and lower the cycle time to 1.5 sec. The FMI will be situated tangent to the Tevatron at the F0 straight section on the southwest side of the Fermilab site. Other possible sitings have been considered, including locations inside the existing Tevatron ring, but these were deemed less desirable than the site shown in this report. The FMI, as described here, is constructed using newly designed (conventional) dipole magnets. The choice of building new magnets is based on considerations of field quality, aperture, and reliability. With the major exception of the dipoles, existing components from the Main Ring are for the most part recycled. Such components specifically include quadrupoles and the radio frequency (rf) systems. The use of all 18 existing rf cavities in a ring roughly half the size of the Main Ring will support an acceleration rate of 240 GeV/sec as compared to 120 GeV/sec in the present Main Ring. The power supply systems described are designed to support this rate.

2.1 Lattice

The design of the FMI is driven by a number of considerations. Given the preferred siting, a maximum physical size of the ring is established by the proximity of the site boundary. This in turn leads to a minimum needed field strength in the magnets. The number and location of the straight sections is determined by the roles the ring is asked to play. In all phases of design the motivation has been to produce a lattice in which the transverse beam sizes are smaller than in the Main Ring over the energy range 8.9 to 150 GeV/c. The two lattice parameters which affect beam size are the beta function, β, and the dispersion, η. In this design β is kept small by using 90° cells with a short distance between quadrupoles. This is a cost effective approach because the quadrupoles will be taken from the existing Main Ring. The η is kept smaller in the FMI than in the Main Ring in part due to the 90° cells, but more importantly due to careful dispersion matching around all straight section insertions. Dispersion matching insures that the maximum dispersion in the ring is no larger than the maximum dispersion in the standard cell. Of course, the FMI will not have overpasses in contrast to the present Main Ring, and therefore, the vertical dispersion will be zero.

<u>Lattice Design</u>

The present Main Ring lattice consists of FODO cells with four dipoles between adjacent quadrupoles. Two of these dipoles (B1) have a 1.5" vertical by 5.0" horizontal aperture and are placed nearest the horizontally focussing quadrupoles. The other two dipoles (B2) have a 2.0" vertical by 4.0" horizontal aperture, and are placed near the vertically focussing quadrupoles. The FMI will use new dipoles with a 2.0" by 4.8" aperture.

Figure 2-1 shows the FMI geometric layout. The standard cell of the FMI is, like the Main Ring, a FODO design but with two dipoles between the quadrupoles as shown in Figure 2-2. The interelement spacing is the same as in the present Main Ring so that the length of the half-cell is shorter by the length of two dipoles and the short drift spaces which follow them, i.e. by about half. Because of the shorter circumference, there are fewer than half as many dipoles as in the Main Ring.

The lattice incorporates two different types of cells, the normal 17.29-m FODO cells and the 12.97-m FODO dispersion-suppressor cells. The latter cells feature shorter dipoles, and reduce the horizontal dispersion to zero in the straight sections. There are 72 normal cells (54 in the arcs and 18 within the straight sections), and 32 dispersion suppressing cells.

The advantages of the lattice include:

i. Zero dispersion in the straight sections. This reduces the horizontal beam size, which in turn makes beam transfers easier to accomplish.
ii. The β-functions in the straight sections and in the dipoles surrounding the straight sections are the same as in the normal FODO cells, affording more clearance for the beam and tolerance in steering at transfer time.
iii. A 136-m long rf straight.
iv. A lattice which accommodates transfer lines to the Tevatron which match the vertical dispersion exactly.
v. A separation of 11.8 m between the FMI and the Tevatron, permitting phased construction of the FMI enclosure.

Having fewer dipoles than the Main Ring leads to higher fields and a larger bending angle. The resulting sagitta in a 6 m dipole is 16 mm. The new dipoles will be built with a curvature which eliminates loss of aperture due to sagitta. A 90° phase advance per cell is chosen, resulting in a maximum β in the cells of 58 meters and a maximum η in the cells of 1.9 meters. By comparison the Main Ring has maximum β and η of 110 and 6.6 meters, respectively. Thus the beam size due to transverse emittance will be only 70% of what it is presently, and the maximum beam size due to momentum spread will be down by a factor of 3 from the Main Ring. The ring has been designed to have twofold rotational symmetry; Figure 2-3 shows the FMI lattice functions for one-half the ring. Lattice functions, as generated by the program MAD, are tabulated in Appendix D.

The 344 dipoles will be excited by 12 power supplies located in six service buildings; the locations of these service buildings are used as the basis for numbering locations in the FMI ring.

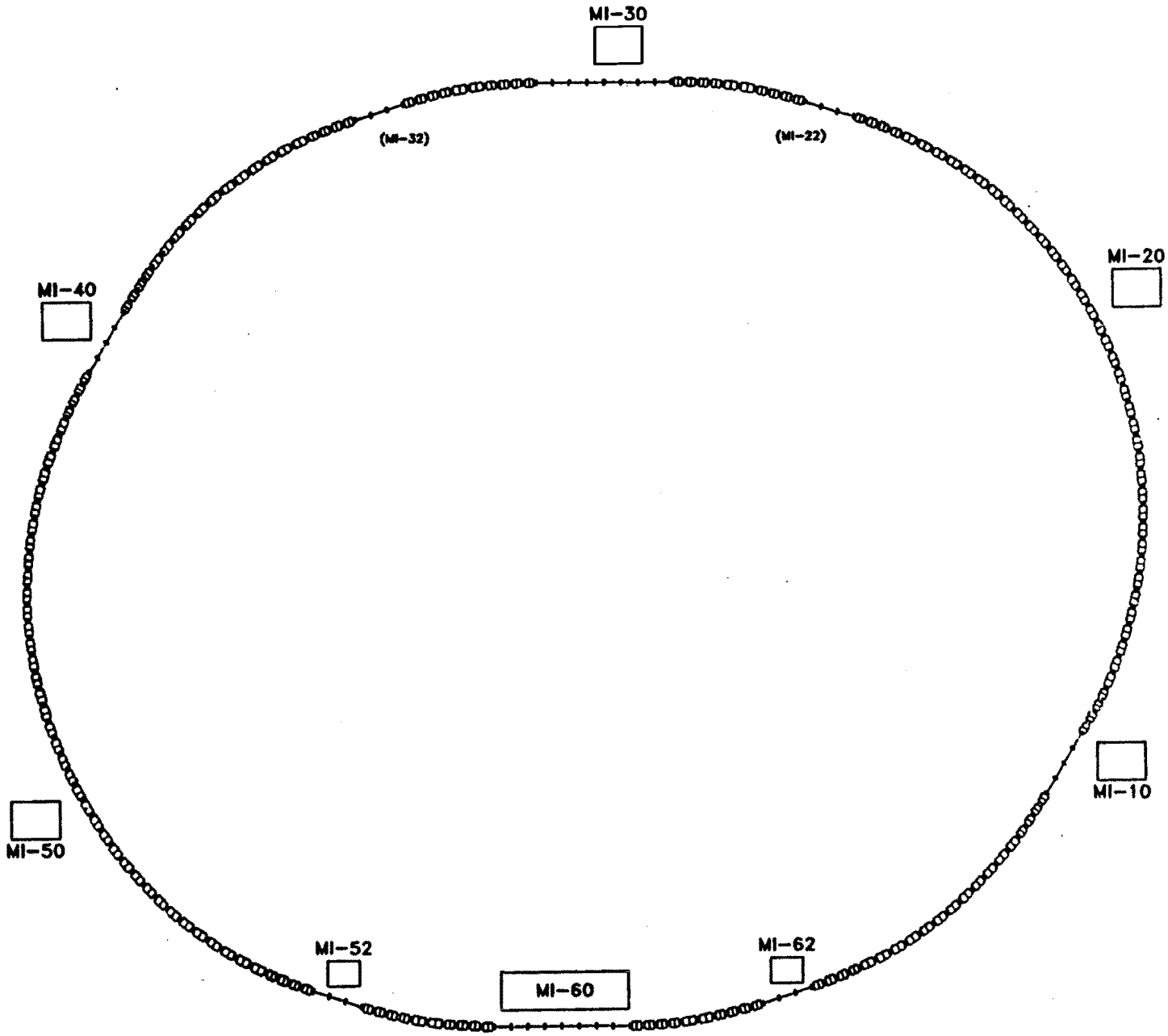


Figure 2-1. Main Injector Geometric Layout
Showing Locations of Service Buildings and Straight Sections

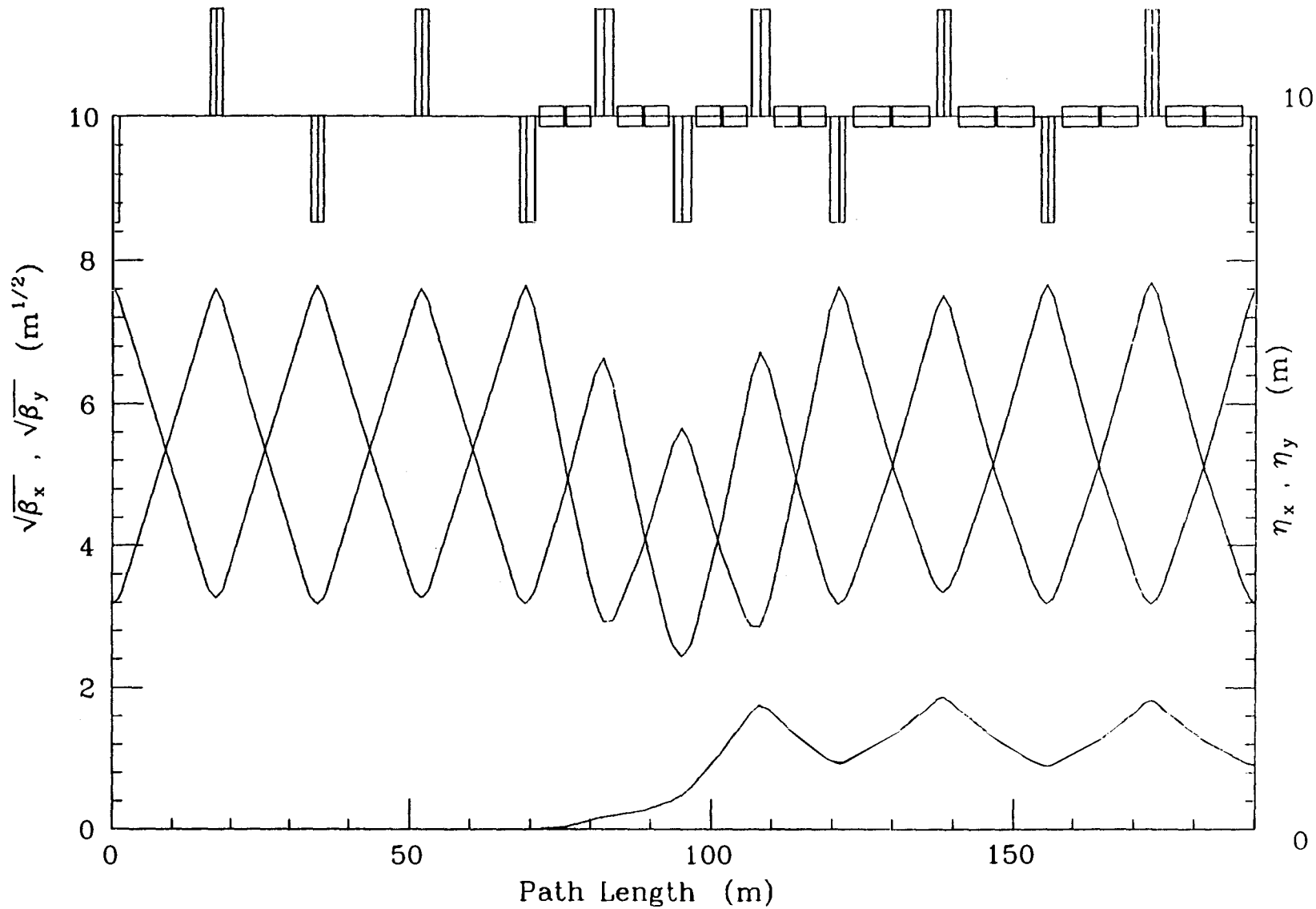


Figure 2-2. Main Injector FODO Lattice showing (left to right) 2 straight-section cells, 2 dispersion-suppressor cells and 2 normal cells.

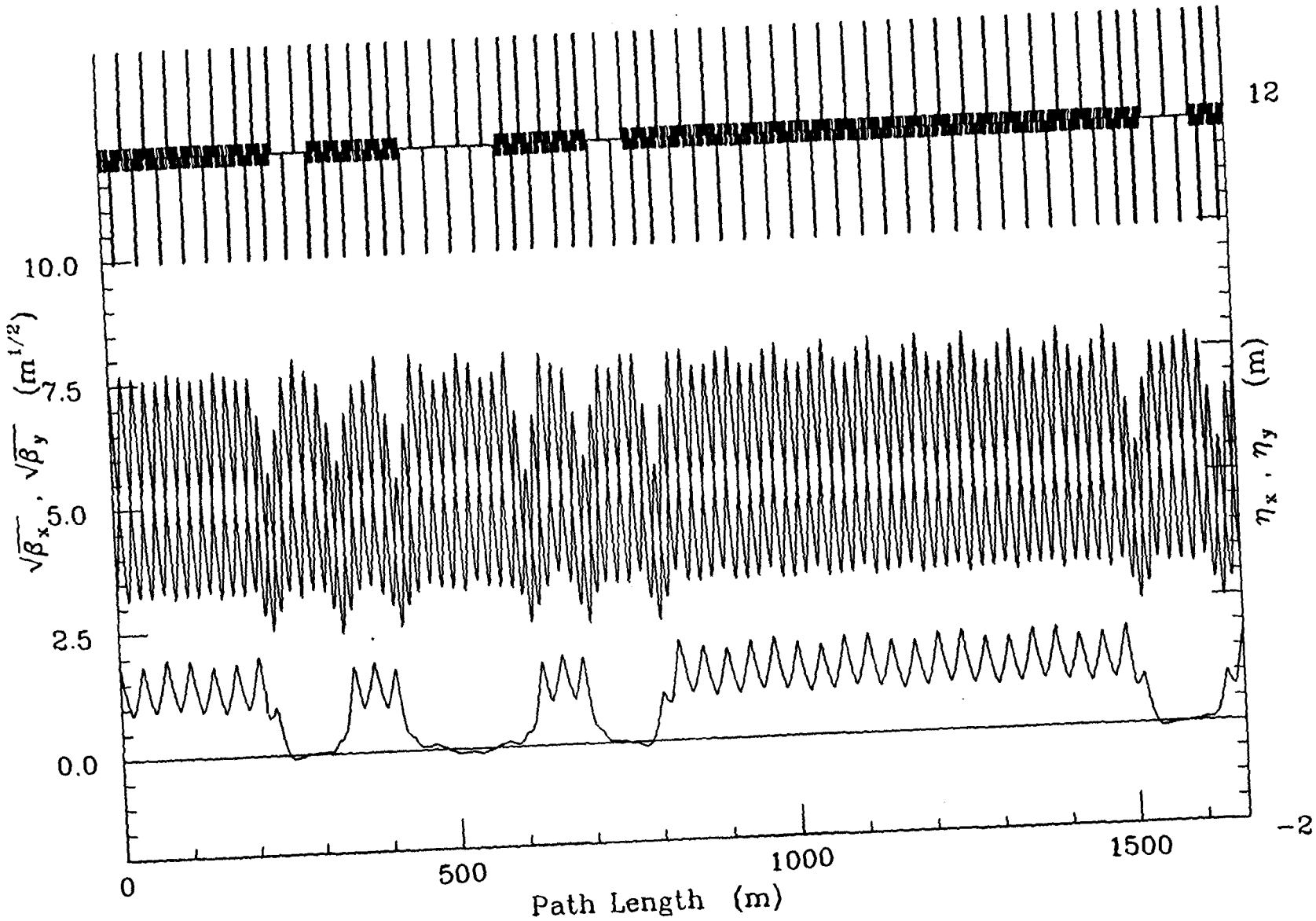


Figure 2-3. Main Injector Lattice Functions for one-half the Ring

The FMI contains eight straight sections. Their locations are shown in Figure 2-1, and a detail of the layout of the MI-52 straight-section is shown in Figure 2-4. Their numbering and their functions are as follows:

MI-10 - 8 GeV proton injection
MI-22 - (unused)
MI-30 - (unused)
MI-32 - (unused)
MI-40 - proton abort
MI-52 - 150/120 GeV proton extraction; 8 GeV antiproton injection
MI-60 - FMI rf section
MI-62 - 150 GeV antiproton extraction

All straight sections are obtained by omitting dipoles while retaining the standard 17.29-m quadrupole spacing. There are three different lengths of straight sections. Straight sections MI-10 and MI-40 are 68 m long (two cells), straight sections MI-22, -32, -52, and -62 are 51 m long (one and one half cells), and straight sections MI-30 and MI-60 are 136 m long (four cells). Straight section 60 is used for the rf; its length will allow flexible spacing of the rf cavities and provide generous free space for diagnostic beam pickups.

Three different quadrupole lengths are required: 2.13-m quadrupoles for the normal cells, 2.95-m quadrupoles for the dispersion-suppressor cells, and 2.54-m quadrupoles at the boundary between the two types of cells. The lengths have been adjusted so that all quadrupoles are powered off two main quadrupoles busses. All straight section insertions are dispersion matched to the cells. With at least 135° of phase advance in each straight section, there is space within the long straight for kickers and septa, a situation not provided for in the present Main Ring lattice.

The long straight sections are capable of beam extraction at the highest FMI energy. Due to the fact the ring lies 11 meters from the Tevatron, two of these (52, 62) are required to provide injection into the Tevatron, one each for protons and antiprotons. On the opposite side of the ring two straight sections (22, 32) are added for symmetry. MI-10 is necessary for injection of protons from the Booster, and MI-40 is placed symmetrically for the proton abort.

The FMI is situated in the southwest corner of the Fermilab site. The details of its location are determined by the requirements of beam transfers of both protons and antiprotons into the Tevatron. The MI-60 straight section is parallel to the Tevatron F0 straight section, separated by 11.823 m (38'9.5") horizontally. The FMI ring lies in a horizontal plane (perpendicular to the gravity vector at the center of the ring) at an elevation of 715'8.7", 2.332 m (7'7.8") below the Tevatron (elevation 723'4.5"). The center of the MI-60 straight section lies directly opposite

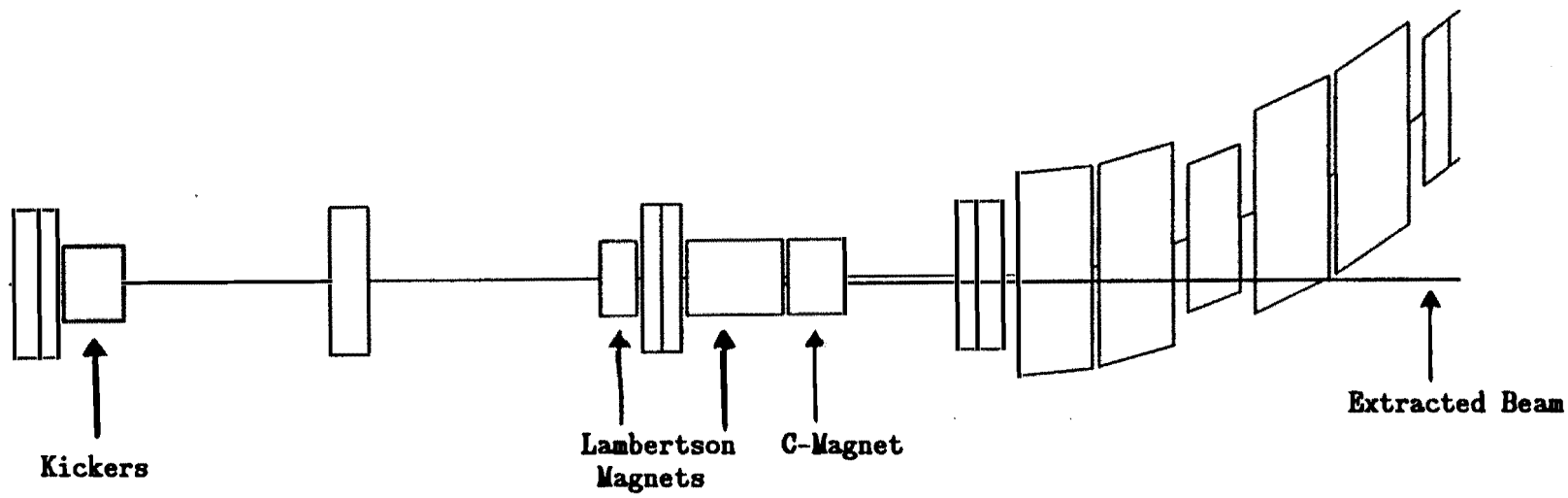


Figure 2-4. Detail (Plan View) of MI-52
used for 8 GeV Antiproton Injection and 120/150 GeV Proton Extraction

the transfer point into the Tevatron, which is 13.222 m (43'4.6") downstream of the center of the F0 straight section. For reference, the FMI tunnel floor will be at an elevation of 713'6", and the Main Ring/Tevatron tunnel floor is at 722'6".

2.2 Acceleration Cycles

There are four basic acceleration cycles, shown in Figure 2-5, serving each of the four operational modes of the FMI:

(a) The antiproton production cycle: 1.5 second cycle, peak energy of 120 GeV.
(b) The 120 GeV slow spill cycle: 2.9 second cycle with a one second slow spill at 120 GeV to the fixed target area.
(c) The Tevatron fixed target injection cycle: 2.4 second cycle for Tevatron injection at 150 GeV.
(d) The Tevatron collider injection cycle: 4.0 second cycle with a 1.4 second flattop at 150 GeV for coalescing.

The operational limits for the rf cavities and power supply systems are discussed in Sections 2.4 and 2.6, respectively. The 18 existing Main Ring cavities in their current running mode are adequate for all of the above cycles.

2.3 Magnets

The FMI uses conventional iron core magnets. A total of 216 6-m dipole, 128 4-m dipole, 128 2.13-m quadrupole, 48 2.95-m quadrupole, 32 2.54-m quadrupole, 108 sextupole, and 208 correction dipole magnets are required. The magnet apertures need to be sufficient to provide a transverse admittance of 40π mm-mr and a momentum aperture of $\pm 1\%$ at transition. The dipole and sextupole are newly designed and manufactured magnets. The 2.1-m quadrupoles and correction magnets are to be recycled from the Main Ring. Dipole and quadrupole parameters are listed in Table 2-1. The sextupole and correction dipole magnets are described in Section 2.5.

The decision to construct the FMI using newly designed dipole magnets is made for several reasons. First, the existing Main Ring magnets are straight. Recycling these magnets into the FMI would result in a loss of about 16 mm of aperture due to sagitta. This aperture is recovered by constructing curved magnets. Second, the existing magnets suffer from reliability problems. Most of the failures in the existing magnets occur at conductor joints within the coil. The number of such joints per magnet will be reduced in the new magnet and at the same time the reliability of the joints improved. Third, it is believed that higher field quality can be achieved in a newly constructed magnet so that the dynamic aperture is only limited by the magnet physical aperture - a situation not achieved in the existing Main Ring.

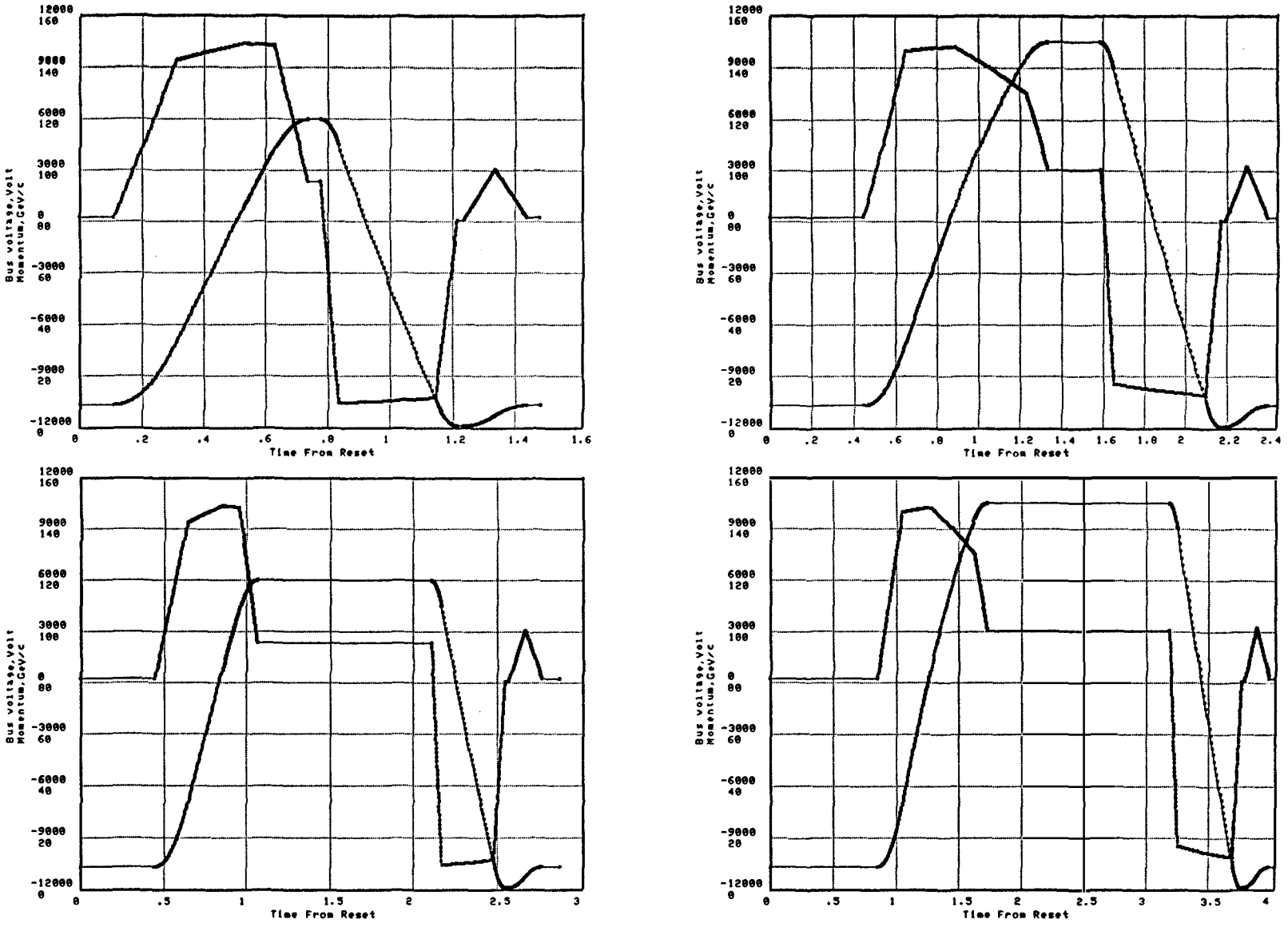


Figure 2-5. Acceleration Cycles

a. 120 GeV Antiproton Production
b. 120 GeV Slow Spill
c. 150 GeV Fixed Target Injection
d. 150 GeV Collider Injection

Table 2-1: Main Injector Magnet Parameters

	Dipole		Quadrupole		
Strength (@150 GeV)	17.2 kG		196 kG/m		
Full Aperture	12x5 cm^2		12x7.6 cm^2		
Turns/pole	4		4		
Maximum Current	9375 A		3630 A		
Length	6 m	4 m	2.1 m	2.5 m	2.9 m
Coil Resistance (mΩ)	0.8	0.6	4.5	5.2	6.0
Coil Inductance (mH)	2.0	1.3	1.3	1.5	1.7
Peak Power (kW)	75	50	59	69	79
Number Required	216	128	128	32	48
Newly Constructed	Yes	Yes	No	Yes	Yes

Once it was decided to build new dipole magnets, a cost optimization was performed which minimized the sum of construction plus operating costs over five years. The result is a magnet with twice as much conductor and half as many turns as the existing Main Ring B2 magnet. The dipole magnet cross section is shown in Figure 2-6. The longer magnet is 6.09 meters long, 1" longer than the Main Ring magnets. The core is constructed from 0.060" thick laminations which are split on the magnet midplane. The coil consists of four turns per pole of a 1"x4" conductor. Since no conductor is contained in the median plane of the magnet, the coil can be wound as two "pancakes" with no bends along the long dimension of the conductor. This conductor is available in 20 ft lengths so each coil can be made with eight joints. The joints will be of a type with demonstrated reliability in which conductors are brazed together with a ferrule inserted between the conductor water holes. The water hole is 0.5" in diameter. A single water circuit in each pancake (two circuits per magnet) provides sufficient cooling.

A four terminal construction has been chosen for the dipole magnet. In a magnet of this design the role of return bus is filled by one of the conductor turns within the magnet. This has the advantage of removing the need for approximately 12,000 ft of 4 $in.^2$ copper bus (@ $40/ft) in the FMI enclosure. The price paid for this benefit is the requirement that the insulation be sufficient to withstand 2,000 volts between conductors within the coil, and 1,000 volts to ground.

MAIN INJECTOR RING DIPOLE

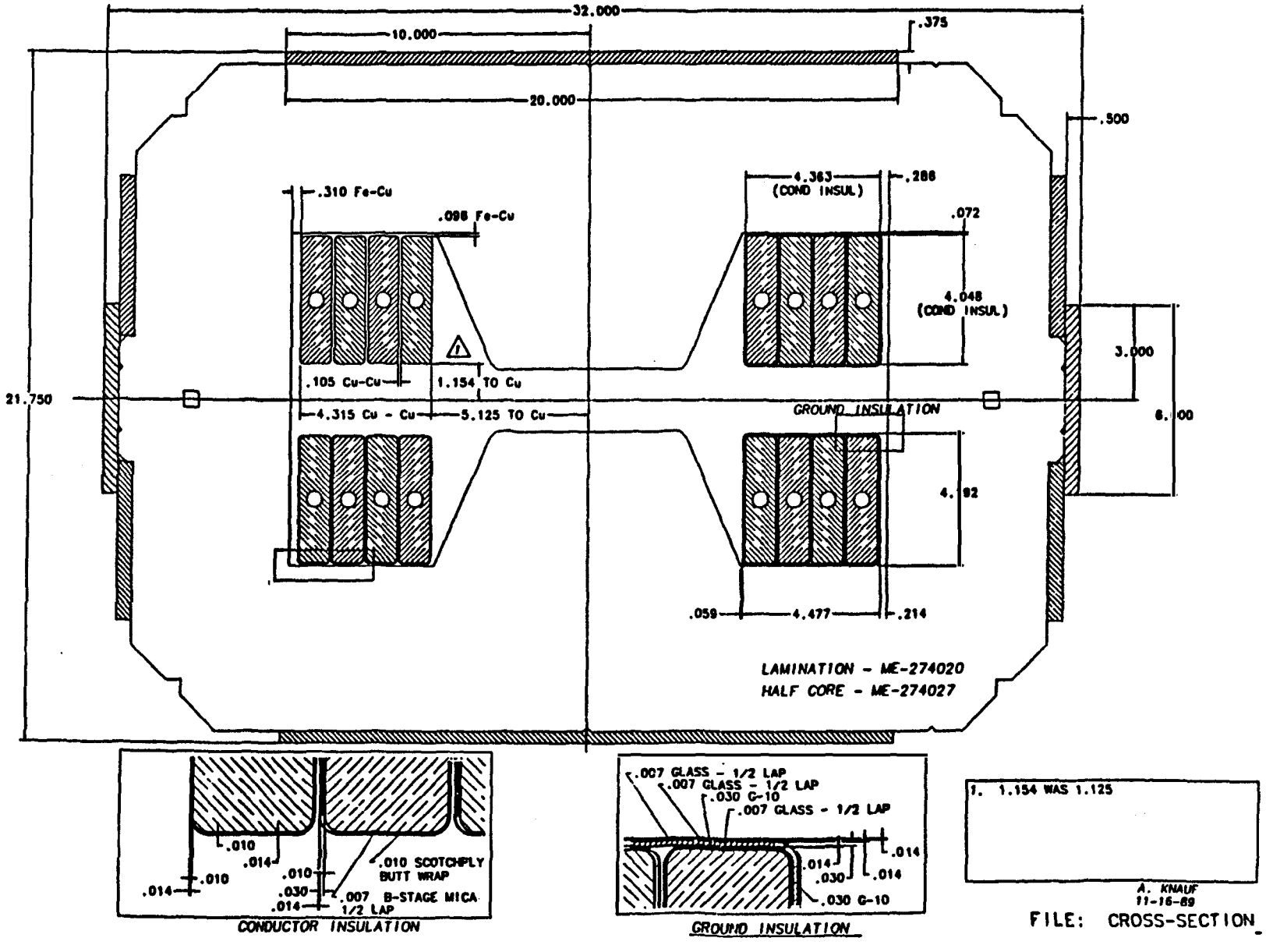


Figure 2-6. Main Injector dipole magnet cross section

Prototype Magnet

The dipole lamination shape is designed to provide a field at the injection energy which varies by no more than 1×10^{-4} over the range $-1.75" < x < +1.75"$. The body field of the first prototype dipole has been measured using four systems: a narrow loop moved in across the aperture ("flat coil"); a rotating coil positioned at three locations across the aperture; a Hall probe; and an NMR probe. From each measurement the field $B_y(x)$ has been reconstructed. Figure 2-7 shows the relative variation from the central field at the injection energy calculated by PE2D, measured with flat coil, and measured with the rotating coil. Agreement is quite good.

At injection energy the field shape is dominated by the lamination shape, and at transition by lamination shape and eddy currents. At the 120 GeV energy used for antiproton production and slow spill some saturation has started to set in on the edges of the aperture, but the 1×10^{-4} tolerance still holds over the range $-0.9" < x < +0.9"$. The beam size at 150 GeV has shrunk to 0.3" (95% full width), so the shrinkage of the 1×10^{-4} region to $-0.3" < x < +0.3"$ is perfectly acceptable. Figure 2-8 shows the measured field shape for 8 GeV, 120 GeV, and 150 GeV. Both flat coil data and fields reconstructed from the harmonics data are plotted, again demonstrating the good agreement. The high-field deviations in field shape are predominantly a sextupolar field; the strength of the horizontal chromaticity-correcting sextupoles is driven by the desire to correct this deviation.

The end packs of the magnets will be tailored to match the field shape of the body of the magnet at injection energy. This will allow use of the same end pack on both the 6-m dipoles and the 4-m dipoles. The precise steel length of the 4-m dipoles will be chosen so that the integrated field strength, including the ends, will be exactly two-thirds of the strength of the 6-m dipoles.

2.4 Power Supplies

The FMI power supply system has been designed to ramp the magnet system from an injection level of 8.9 to 120 or 150 GeV/c excitation at a repetition rate adequate to meet requirements for Antiproton Source stacking, Tevatron injection, and slow spill operations. The power system consists of 12 new rectifier power supplies for the bend bus, reuse of existing equipment on the quadrupole bus including six main bus supplies, a new power feeder system for all the supplies, a new harmonic correction system, and the reuse of many smaller items from the present Main Ring. A summary of the FMI power supply requirements is given in Table 2-2.

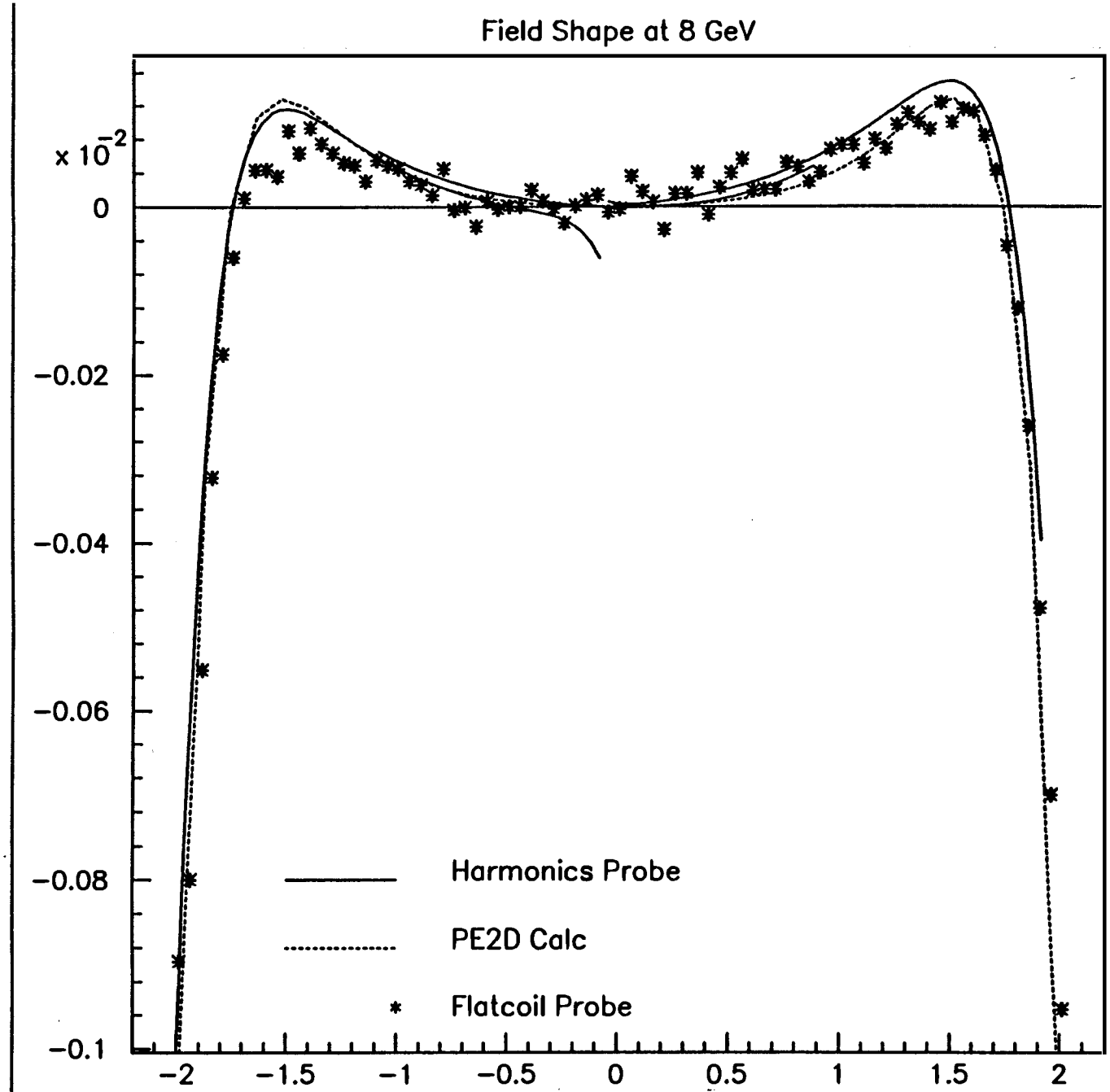


Figure 2-7. Magnetic Measurements at Injection Energy

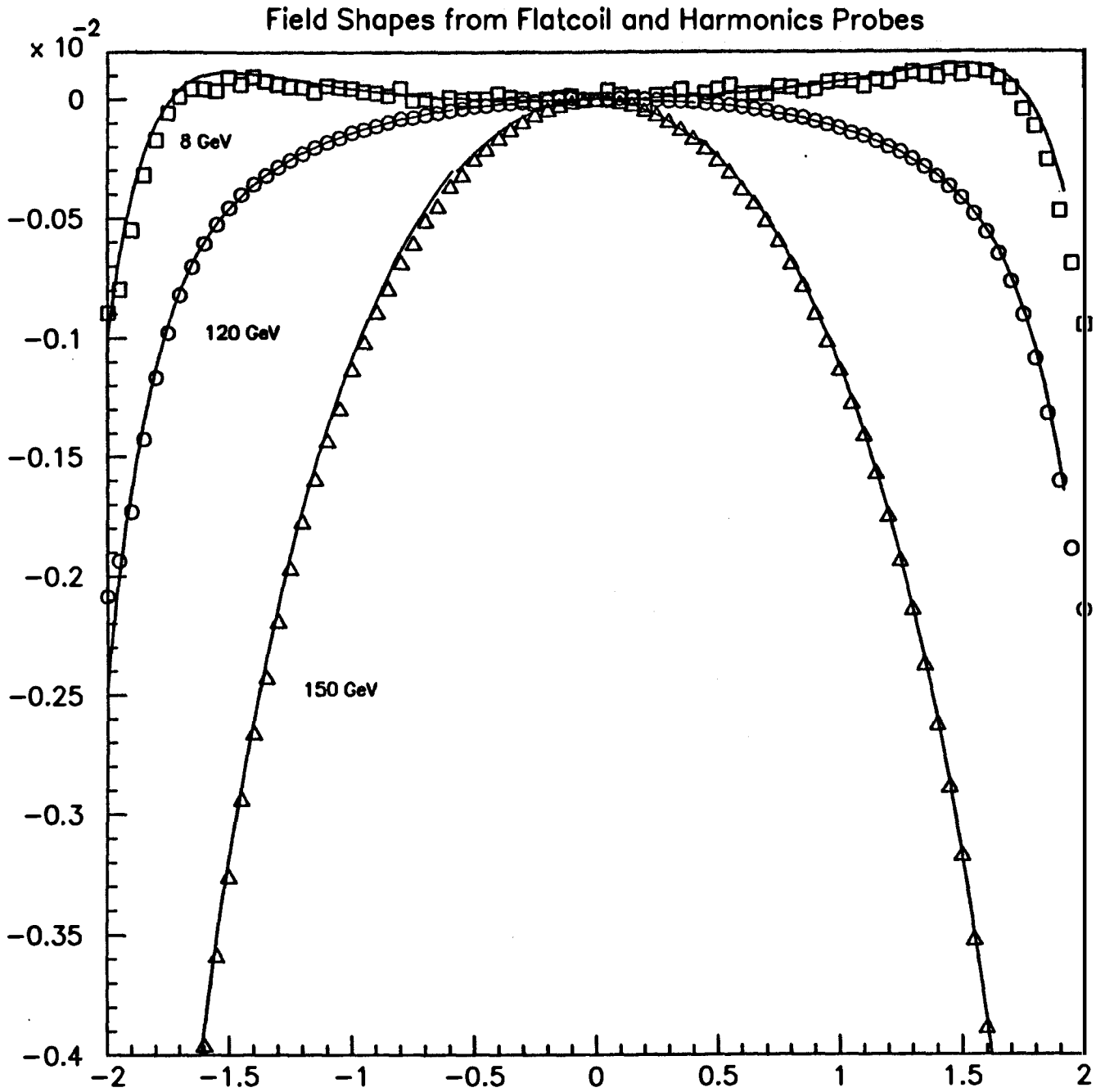


Figure 2-8. Magnetic Measurements at various Energies

Table 2-2: Power Supply Summary for the FMI System

	Power Supplies	Voltage	Maximum Current
Bend	12 new	1,000 V	9,375 A
Quad F	3 old	850 V	3,630 A
Quad D	3 old	850 V	3,630 A
Other Equipment Needed:			
Quad regulator	2 new	300 volts	500 A
Regulation			
Transductors	2 new		10,000 A
Transductors	2 new		5,000 A
Computer link	1 new		
Harmonic filter	1 new		

Power supply spacing for minimum voltage-to-ground requires an equal impedance between power supplies on the dipole bus. The proposed system will have six service buildings with two dipole supplies per building, one on each of two busses, and one quadrupole supply. The buildings are spaced so that there are 25 6-m dipole magnets (or an equivalent mixture of 4-m and 6-m dipoles) between each supply, with the magnets on a folded bus loop. The third supply in each of the six buildings is configured such that three are in series with the focussing quadrupole magnet bus; three are similarly used with the defocussing quadrupole bus.

Criteria for Ramps and Constraints on Power Supply Layout

The overriding design criterion was to design a combined magnet and power supply system that would be cost effective during operation. A system was chosen to have low power consumption and a safe power supply voltage without being unduly expensive to construct and unwieldy in physical size. Two new 40 MVA power distribution transformers located at the new Kautz Road Substation will be used in the new installation with an operational limit set at 120 MVA peak and an rms value of 60 MVA. There will be a 13.8 kV feeder cable system installed in a triple loop around the FMI ring. The rms current rating of the entire system is 2,700 amps.

The maximum rate of rise will be set by the use of the existing Main Ring rf system, which has at present an operational limit of about 240 GeV/sec. The maximum ramp repetition rate is set by the 2,700 amp feeder current limit and a chosen rms dipole bus current of 5,000 amps.

The dipole configuration is two busses internal to the new magnets with a fold at MI-60 allowing for six upper bus supplies and six lower bus supplies. The impedance of the magnet load in the FMI dipole bus is 0.6 Henries and, with the use of 4 in.^{2} cross section copper for the magnets and power supply bus, will have a dc resistance of 0.32 ohms. The required peak power supply voltage is 12 kV for the bend bus.

The quadrupole configuration is two separate busses in continuous loops around the injector with current flowing in opposite directions, one focussing and one defocussing, each having three supplies for ramping and a transistor regulator supply for injection current regulation. Each quadrupole magnet loop impedance is 0.15 Henries, and with the use of 2 in.^{2} power distribution bus, will have a dc resistance of 0.3 ohms. Thus the required peak power supply voltage is 1,500 volts for each quadrupole bus.

Ramp Details

The ramp details are determined by a number of limitations which enter at various points in the ramp: rf voltage; power supply voltage; feeder currents; etc. For antiproton stacking, the voltage and number of power supplies are chosen to provide a repetition rate of 1.5 seconds with a maximum rate of rise of 240 GeV/sec. Figure 2-5 and Table 2-3 give details on the four modes of operation. The fixed target injection ramp requires only a short flattop. The collider injection ramp will need a longer flattop, but is only run at a low repetition rate. The fixed target injection ramp is intended to be run twice in succession, once a minute, with 120 GeV cycles the remainder of the time. The transformers for the FMI are being sized for a current (average between peak and rms) of 6,500 amps. If the fixed target injection ramp is run repetitively (for studies) the repetition rate must be slowed to reduce the rms current to ~3,600 amps (~5.4 sec rep rate).

With 12 kV maximum power supply voltage, the ramp rate will need to decrease above 80 GeV from 240 GeV/sec to 225 GeV/sec at 108 GeV. This is required due to the lack of power supply voltage to maintain high inductive voltage and high resistive voltage at the same time. The lower rate of rise slightly increases the rms current in the magnets and feeders.

Feeder current limitations require the ramp rate to decrease more dramatically above 120 GeV, to 120 GeV/sec at 144 GeV. The result of this restriction is that as one approaches the parabola coming into flattop, no more than nine power supplies can be turned on. Ramp regulation which puts supplies into bypass is required. While this lowers the peak feeder currents, it raises the peak voltage-to-ground and bus-to-bus voltage that the magnets experience.

Table 2-3: Main Injector Ramp Parameters

Ramp	Fixed Target	Collider Injection	Antiproton Production	Slow Spill	
Peak Energy	150	150	120	120	GeV
Cycle time	2.40	4.0	1.4667	2.8667	sec
Time (Booster cycles)	36	75	22	43	
Injection Dwell	.441	.841	.108	.441	sec
Flattop	.250	1.45	.040	1.04	sec
DIPOLE BUS					
Max. Current	9375	9375	7100	7100	A
RMS Current	5434	6659	3765	4988	A
Power	9.4	14.2	4.5	8.0	MW
RMS Feeder Current	1991	1311	2054	1473	A
Peak Feeder Volt-Amps	98	98	94	94	MVA
Average Feeder Volt-Amps	48	43	49	35	MVA
QUAD BUS (sum of both)					
Max. Current	3630	3630	2904	2904	A
RMS Current	2095	2567	1540	2040	A
Power	4.8	7.1	2.5	4.4	MW
RMS Feeder Current	444	584	316	336	A
Peak Feeder Volt-Amps	21	21	16	16	MVA
Average Feeder Volt-Amps	11	14	8	8	MVA

Power Supply Control

The power supplies are assumed to be controlled differently on different cycles. For the fast cycling 120 GeV cycle (with very short flattop) one power supply is used at 8 GeV, but as the ramp begins, the remaining power supplies are turned on simultaneously. For the 150 GeV cycle, the supplies are turned on and off as required by voltage demands, with either 1,4,8,10 or 12 supplies on at once. For the 120 GeV slow spill cycle, 1,3 or 12 supplies are energized. This sequential turn-on is required to minimize voltage-to-ground distributions and rms feeder currents.

Studies on the Main Ring supplies indicate that the regulation will not be degraded in going to a ramp rate of 240 GeV/sec, twice that of the Main Ring, with no changes in the power supply control. The regulation of the FMI power supply system will be further improved by providing two 24-pulse power supplies, one of which will be used as the regulating power supply and the other as a spare. The remaining ten supplies will remain 12-pulse.

Power Feeder Loading

The main 13.8 kV power feeders have an operating limit of 2,700 amps rms. The power supplies around the ring will be supplied in a three feeder loop to ensure proper current sharing. More details are given in Section 2-14.

The use of rectifier power supplies on this system draws current pulses from the feeders which then drive harmonic resonances, causing higher voltages at the resonant frequencies to be imposed on the power equipment. The present Main Ring has an harmonic filter to limit the peak voltages of higher frequencies superimposed on the 60 Hz line voltage. The FMI will run with 12 power supplies at 120 MVA peak versus 70 MVA for the Main Ring, requiring the filter to damp more harmonic power. Therefore, in the FMI a new filter needs to be designed to correct for the higher harmonic driving force of the system. This new filter will be installed at the switch in the feeder system where the feeders change from direct feed to loop feed (near the MI-50 service building), and will consist of a new section in parallel with the Main Ring filter.

2.5 Correction Elements

The FMI correction element inventory includes steering dipoles, trim quadrupoles, skew quadrupoles, sextupoles, skew sextupoles and octupoles. Wherever possible existing components will be reused. The steering dipoles, trim quadrupoles, skew quadrupoles, skew sextupole and resonance-compensating sextupoles will be recycled Main Ring components. The chromaticity-controlling sextupoles will be a modified version of the Antiproton Source sextupole. Correction elements will be placed next to each quadrupole. A horizontal (vertical) steering dipole will be placed at each focussing (defocussing) quadrupole. Sextupoles will be placed next to quadrupoles in the arcs where the dispersion is large. The trim quadrupoles and skew quadrupoles will be placed around the ring as needed. In addition, a small number of sextupoles to cancel harmonics due to the chromaticity sextupoles will be located in the straight sections. A typical installation showing the ends of two dipoles, the lattice quad, a chromaticity sextupole, a trim quadrupole, and a correction dipole, is seen in Figure 2-9.

Steering Dipoles

The steering dipoles correct the closed orbit. The primary sources of orbit distortion are quadrupole placement errors, dipole strength errors, and dipole rotations. These errors cause orbit distortions proportional to β, which, if uncorrected, would yield rms errors on the order of 6 mm. Although the present Main Ring trims have adequate strength for correcting these errors at low field, the effort of shimming and recentering them and engineering a new mounting scheme is nontrivial. Therefore, new trim dipoles for the FMI ring will be fabricated, with strengths a factor of two greater than the present Main Ring correctors, allowing correction of errors up to 4 mm

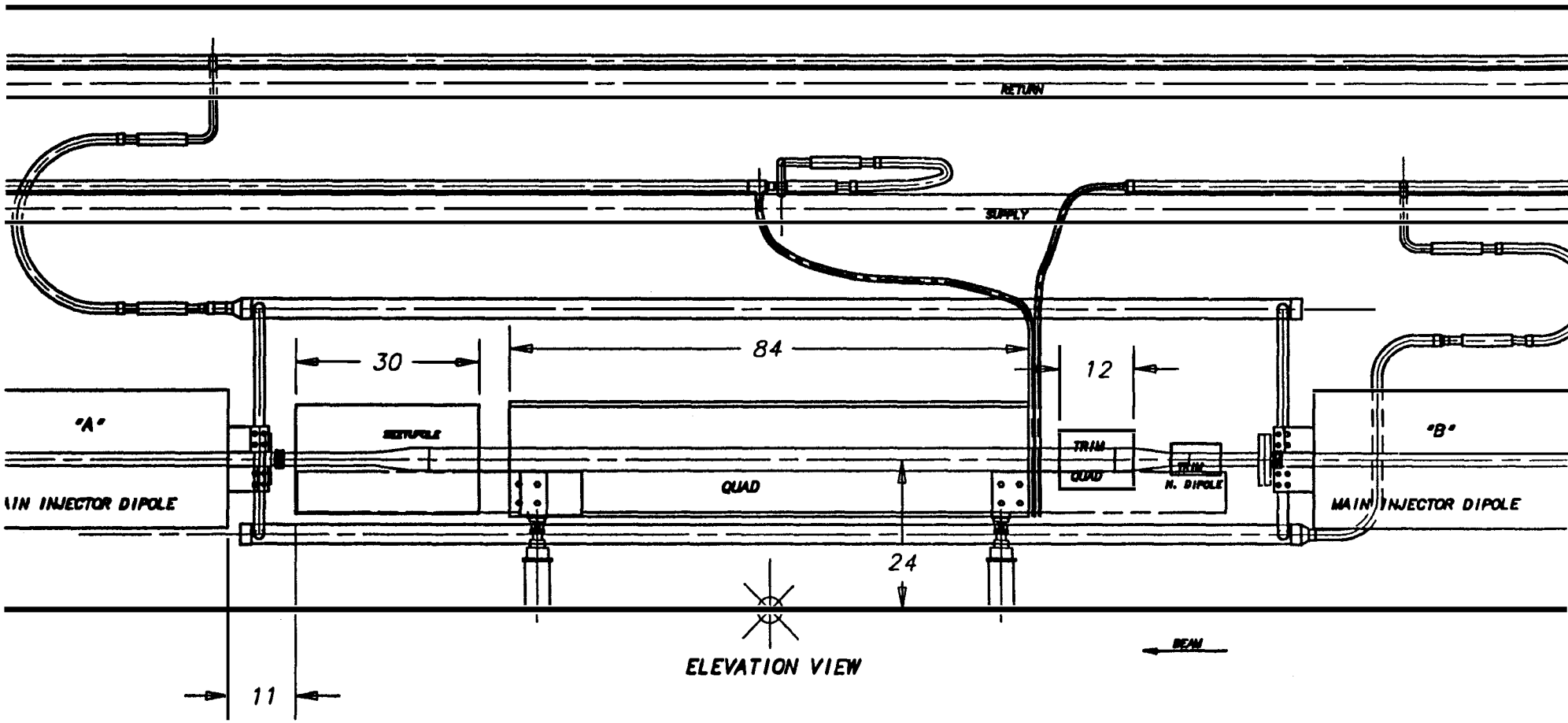


Figure 2-9. Layout of a typical Main Injector Quadrupole and Trim Magnets.

horizontally (3 mm vertically) at 150 GeV. The Main Ring correctors will be used in the beamlines, providing correction at every quadrupole, which requires 60% of the existing correctors. The power supplies will be moved from the Main Ring to the FMI to allow programming the steering dipoles through the acceleration cycle.

Trim Quadrupoles

The main quadrupoles of the FMI will run on two separate busses and will be used for all necessary tune adjustments. Trim quadrupoles are needed for harmonic generation or cancellation. A sufficient number of Main Ring trim quadrupoles will be installed around the ring to cancel half-integer stopbands, if they are significant. In addition, slow extraction will require a small number of trim quadrupoles for excitation of the half-integer resonance.

Sextupoles

Sextupoles will be used primarily for correction of the FMI chromaticity. The natural chromaticities of the FMI are -33.65 horizontally and -32.87 vertically. The lattice has been designed to have low β and η (58 m and 1.9 m are the maximum values in the arcs). Thus, very strong sextupoles will be needed to cancel the natural chromaticity. The configuration chosen places an F(D) sextupole at each F(D) main quadrupole in the arcs where η is large. Fifty-four of each sextupole type will be needed. There are also large sextupole components in the dipole magnet induced by saturation of the steel as the beam energy approaches 150 GeV (horizontal sextupole) and by eddy currents in the beam pipe (vertical sextupole). These effects produce "natural" chromaticities of -77 horizontally (at 150 GeV) and -55 vertically (near 20 GeV). The correction sextupole magnets must also be capable of compensating this effect. Based on a requirement that the sextupoles be capable of producing a corrected chromaticity of +20 in each plane the sextupoles are designed to have a maximum field strength of 625 kG/m^2-m. These magnets will be similar to the debuncher sextupoles built for the Tevatron I project, but with a reduced aperture (4.25" vs. 5.625") and increased length (24" vs. 8").

With the strong sextupoles required in this ring there may be some concern that the dynamic aperture of the machine might be adversely affected. Tracking studies completed to date indicate that there is no loss of dynamic aperture due to the sextupole correction system. However, we will still distribute eight individually powered sextupoles for control of third order resonant driving terms.

Skew Quadrupoles

Prelimary work has begun on calculating the magnitude of the coupling in the FMI. Twelve skew quadrupoles will be installed to cancel coupling. They will be recovered from the Main Ring.

2.6 Radio Frequency System (rf)

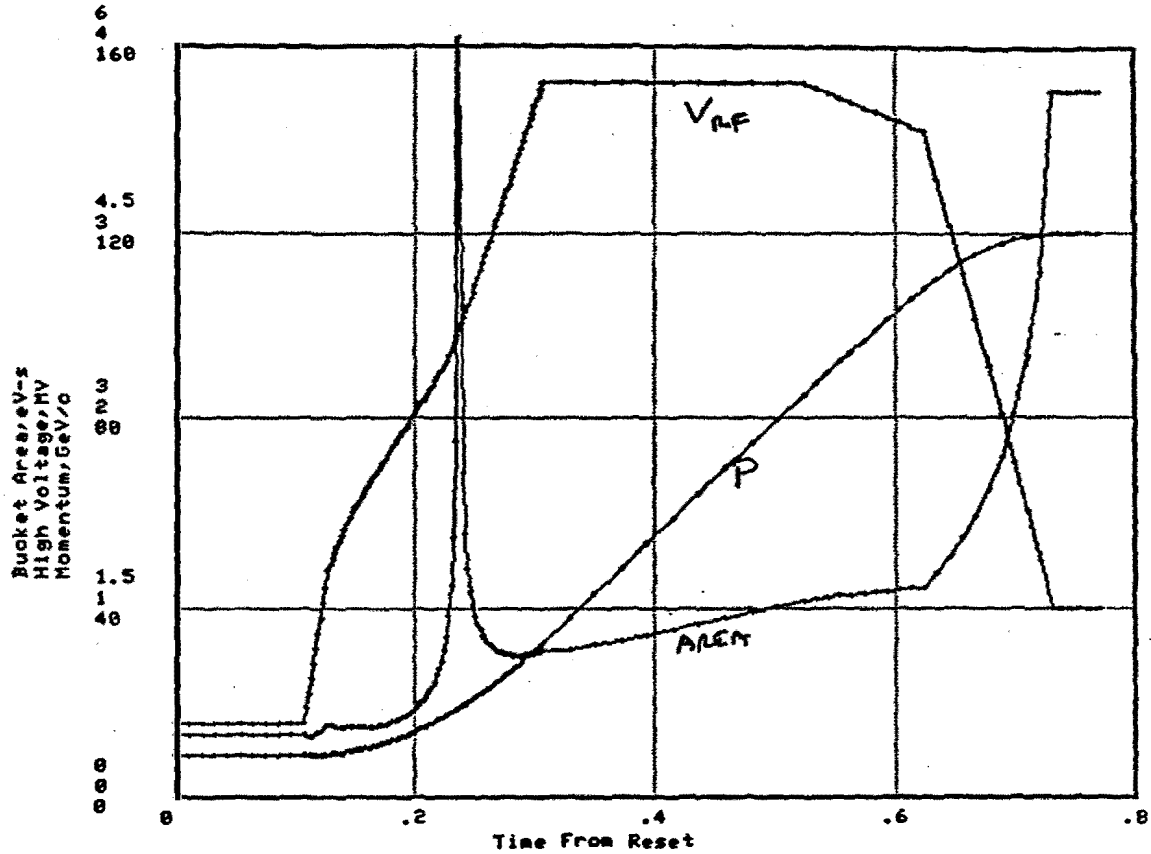
h=588 cavities

The 18 existing 53 MHz Main Ring rf cavities will be installed in straight section MI-60 and operated at harmonic number 588. The operating levels below transition are determined by an interplay between cycle time, bucket area, and synchrotron frequency. A bucket area of at least 0.5 eV-sec is required to accept beam out of the Booster. Historically, it has been necessary to keep the synchrotron frequency in the Main Ring below 720 Hz to avoid resonance with power supply ripple at the sixth harmonic of the line frequency. Figure 2-10 shows the rf voltage, bucket area, synchrotron frequency, and synchronous phase through the 120 GeV antiproton production cycle. A bucket area of 0.5 eV-sec is maintained, but with the synchrotron frequency rising above 720 Hz. The ramp would have to be slowed down to avoid this. The momentum spread in the beam, $\delta p/p$ (95% half width), is ±0.2% at injection, increasing to about ±1.0% near transition, and decreasing to ±0.1% at extraction.

Since the FMI must accelerate antiprotons as well as protons, a degree of simplicity can be achieved in the fanout/fanback system by placing the cavities at spacings that are multiples of one-half the rf wavelength. The elimination of the present switching system will increase the system reliability and provide greater flexibility in cavity control during coalescing.

The rf system has the capability of generating enough voltage at injection to produce a 1.0 eV-sec bucket area at injection. In this mode the synchrotron frequency lies well above 720 Hz at injection and descends rapidly, crossing 720 Hz when the beam energy is about 15 GeV. Operational experience will dictate which scenario is used.

One drawback of the existing Main Ring rf system is the power that it can deliver. The present requirements are 55 kW per cavity, which will grow to 70 kW after the Linac upgrade. The FMI will require 112 kW for accelerating the full intensity at 240 GeV/sec, which is close to the present capability. To overcome this limitation, new 200 kW power amplifiers and 30 kV series tube modulators will be provided. The new 200 kW amplifiers will be a cathode-driven, grounded-grid design with the cathode having a dc bias voltage. The design will retain the existing Main Ring final PA tube module. The cathode of the final tube will be biased by a new 20 amp, 500 volt supply and be driven through a matching network by a new solid state 5 kW rf driver. A Tevatron power amplifer (grid biased to -230 volt) has already produced more than 200 kW of output power when the final tube cathode was driven by 4 kW of rf drive power. This demonstrates the feasibility of the new design and is also a possible alternative to the biased cathode design.



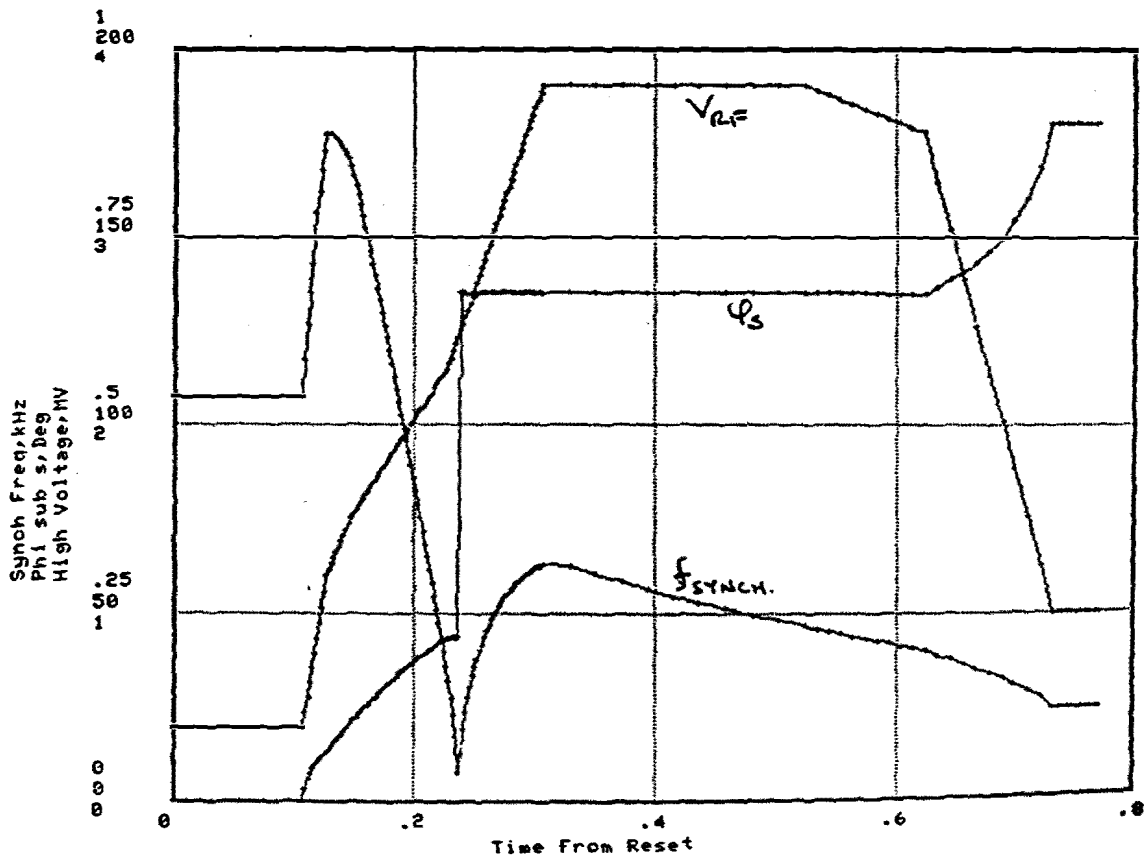


Figure 2-10. RF parameters for the 120 GeV antiproton production cycle.

The transient beam loading from 6×10^{10} protons per bunch will require about 1.25 amp delivered to the cavities, supplied by 15 amp (12:1 cavity step-up ratio) of rf current generated by the power amplifier. A 200 kW rf power amplifier operated at a dc plate voltage of 20 kV will produce a peak rf current of approximately 21 amp providing 40% surplus capability.

Coalescing Cavities

The Main Ring coalescing rf cavities (2.5 MHz and 5 MHz) will also be employed in the FMI for use during collider loading. The change in harmonic number, coupled with the change in γ_t, results in the coalescing cavity bucket height increasing by a factor of 1.5 relative to the Main Ring. This should improve the coalescing efficiency, enhancing the ability to make bunches of the desired intensity for delivery to the Tevatron collider. Alternatively, if the need arose the voltage in these cavities could be reduced keeping the coalescing bucket height the same as currently used in the Main Ring.

Transition Crossing

Concerns over emittance dilution (Johnsen and Umstätter effects) during transition crossing have led to a prosposal for a higher harmonic cavity which will avoid the rf-focussing effects which contribute to the dilution. Results from simulations of transition crossing in the presence of a second harmonic rf voltage for the FMI are very encouraging. Presently the Main Ring longitudinal emittance is about 2.5 times smaller than that for the FMI, and a third harmonic rf cavity should be enough to reduce the emittance blow-up during transition crossing. Therefore, an experiment to study transition crossing in the Main Ring using a third harmonic rf cavity was proposed and is underway. For this purpose, a single-cell 200 MHz copper rf cavity has been acquired from CERN and modified to resonate at 159.09 MHz. The cavity is required to operate in the frequency range of 159.059 MHz to 159.123 MHz during the transition crossing. This frequency swing is about a factor of 4 larger than the natural resonance width of the cavity. To tune the cavity in this frequency range a low loss orthogonally biased tuner using Trans-tech G510 ferrite has been built and tested. Also, a power amplifier which is capable of delivering sufficient third harmonic current to excite the cavity to full amplitude of 280 kV has been built. This cavity is being installed in the Main Ring and will be tested during the next collider run. If such studies successfully demonstrate the ability to transmit the beam through transition without blow-up, then construction of a dedicated second harmonic cavity for the FMI will be undertaken.

2.7 Vacuum System

The vacuum system for the FMI will be similar to the Main Ring system. Each dipole magnet chamber will have two ports for 30 liter/sec ion pumps, with three pumps installed on each pair of dipoles. The fourth port will be

blanked off or fitted with a valve for connecting temporary pumping capacity. The straight sections will have a port approximately every six meters for the same type of pump. Care will be taken in the design of the vacuum chamber to limit the impedance presented to the beam. Ion pumps from the Main Ring will be reused. The stainless steel vacuum chambers will be electro-polished and baked at 400°C. Since 5 cm aperture magnets are used throughout the FMI, the conductance will be higher, and an average pressure lower than the Main Ring should be achievable. The design goal is an average pressure of 1×10^{-8} Torr. With this pressure the beam lifetime will be an order of magnitude larger than in the Main Ring.

Gate valves will be used to divide the FMI into sectors. There will be a gate valve at the end of each straight section with appropriate interlocks. There will be a total of 32 gate valves in the system.

The beamlines will use 30 liter/sec ion pumps of the same type as the FMI, spaced approximately every 12 meters.

Vacuum pressure during pump down will be monitored by a combination of thermocouple and cold cathode gauges; high vacuum will be monitored by the current readout of each ion pump. Vacuum pump down will be done using portable turbomolecular units that can be wheeled to any area being worked on. Ten units are provided.

2.8 Instrumentation

Beam Position Detector (BPM)

The beam position system for the FMI is patterned after the existing Main Ring system. At each F(D) main quadrupole there will be a horizontal (vertical) pickup. Twenty quadrupole locations in the vicinity of beam transfer points will have both horizontal and vertical pickups. New BPMs will be built for the FMI. The processing electronics are the Fermilab standard amplitude-to-phase conversion style with a center frequency of 53 MHz. The system will be capable of producing first turn orbits, turn-by-turn readouts, and closed orbits.

Beam Loss Monitors (BLM)

The loss monitor system will utilize the recently constructed Main Ring ion chambers at each quadrupole in the ring and be of the same type as the present Tevatron system.

Other Special FMI Diagnostics

The FMI will employ a second harmonic dc current transducer. This will enable accurate acceleration efficiency measurements and will also be used for dc storage studies.

In order to analyze longitudinal and transverse instabilities, the FMI will be equipped with a broadband longitudinal pickup and two broadband transverse pickups, one for each plane. These detectors should be very useful in studies of coupled bunch and head tail instabilities common to such high intensity rings.

The FMI will also be equipped with three flying wires to allow dynamic emittance and momentum spread measurements during acceleration.

Dampers and Scrapers

The FMI damper systems will be patterned after the Tevatron bunch-by-bunch system. The system will allow damping of injection oscillations and coherent instabilities, as well as providing the capability of knocking out selected bunches or heating the beam transversely in either plane.

The FMI will have beam scrapers for measuring the acceptance of the machine in both planes and a momentum scraper to aid in beam transfer function measurements.

2.9 Controls

The entire accelerator complex, from the ion source to the Tevatron and antiproton rings, is controlled by a uniform system known as ACNET (shown in Figure 2-11). As shown, each accelerator subsystem has a front end computer which drives a link attached to all appropriate hardware for that subsystem; all links constructed recently are CAMAC while some older systems utilize different technologies. Application programs and file storage, as well as a central database detailing all electronic components, are under control of VAX computers networked to the front ends. Also connected to this network are a number of operator consoles, attached in such a manner that any console can monitor and control any accelerator.

ACNET is currently being upgraded in a number of important aspects, with more modern hardware and software being added. However, the basic structure described is not being changed. A recent major upgrade was the reworking of Main Ring controls in CAMAC. Much of the FMI hardware will be these CAMAC modules and associated equipment moved to the new location. Also ongoing as part of the Main Ring upgrade is the installation of 24 channels of fiber optic cable as the conduit for various controls and timing links. Similar cable will be used for the FMI, with a path from the Cross Gallery roughly along the 120 GeV beamline. This path is chosen so that beamline controls can be handled by these same links.

The FMI fits naturally into the existing system. To the current complement of ten front ends will be added one for the FMI; there exists sufficient network bandwidth and VAX computer cycles that this addition can be

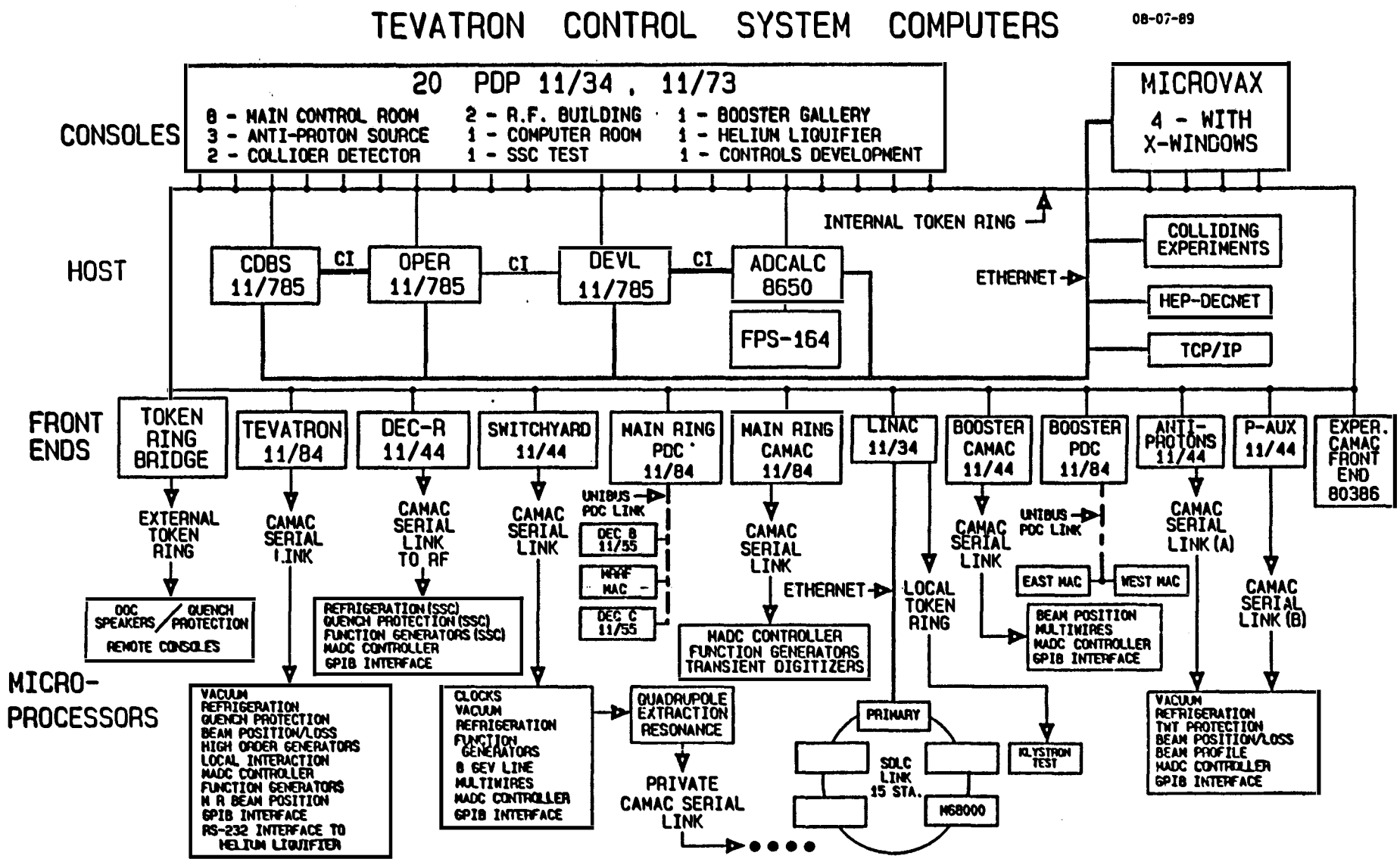


Figure 2-11. Schematic diagram of the Accelerator Controls Network (ACNET).

made with minimal impact. (Remember the Main Ring will be disappearing.) A new front end is needed because the one installed for the Main Ring system cannot be easily moved since it has been convenient to attach some Tevatron devices to it. The new computer will drive a CAMAC link running to and around the FMI; this link will connect to a number of crates and relay racks, and will have a number of cable terminations, scaled according to experience with the Main Ring. Twelve thousand feet of fiber and 84 repeaters are appropriate to provide this link, as well as to distribute timing signals and real-time accelerator data, and to extend the laboratory-wide Token Ring network.

Since most of the new hardware connected to the control system will be copies of existing modules, the software effort necessary for support is expected to be manageable. Applications and front end code should be straightforward migrations of what is currently being created for the Main Ring. However, there are other computers associated with the current Main Ring beyond those normally associated with data collection. The ramp is presently generated by a pair of PDP-11's (DEC-B and DEC-C), which are in the process of being replaced with 68040-based processors. With the variety of FMI operational modes some software effort may be needed in transferring these machines to the FMI, although the initial implementation of these will be done with the FMI in mind.

The Main Ring high level rf is controlled by one of the few remaining Lockheed "MAC" computers in the Laboratory, along with its associated MIU (module interface unit). A new computer and hardware system, and associated software effort, will be required for this function.

2.10 Abort System

The proposed proton abort system for the new FMI relies heavily on the technology and design utilized in the existing Main Ring abort system commissioned in 1983. This system has successfully provided clean single-turn abort capability for all subsequent Main Ring proton beam operation. The abort system for the new FMI reuses much of the hardware of the present Main Ring system, with the exception of the beam dump. Because of the low intensities transported, there is no $\bar{p}$ abort.

The system will track the energy of the FMI ring, and be capable of aborting the beam at any point in the 8.9 - 150 GeV/c range, within 50 μsec (5 turns) of the abort command. A 1.5 μsec abort kicker risetime matched to a corresponding minimum gap in the circulating beam allows abort efficiency approaching 100%.

Two 2.2-m long kicker magnets are located at the upstream end of long straight section MI-40. The peak kicker field required is 1.9 kG with the 90° phase advance between the kicker location and the Lambertson magnets at the

center of the long straight section. The first of these will be located upstream of the quadrupole in the middle of the straight section. A horizontal displacement of the aborted beam of 28 mm (at 150 GeV) to 38 mm (at 8 GeV) at the first Lambertson magnet positions the beam appropriately for the abort channel.

The two Lambertsons and one C-magnet, with peak fields of 11 kG, deflect the aborted beam vertically downward at an angle of 24 mr so as to clear the quadrupole at the downstream end of straight section MI-40 and exit the FMI tunnel toward the abort beam dump. The geometry of the MI-40 straight section is similar to that of MI-52, shown in Figure 2-4. The aborted beam will pass through a short quadrupole and through two B2 magnets rolled at a 40 degree angle. The rolled B2s level the beam off and deflect it outwards, so that the abort beamline remains above the floor level and diverges from the circulating beam more quickly, simplifying the civil construction of the straight section. Two additional quadrupoles further downstream maintain a reasonable beam size up to the beam dump. The Lambertson, C-magnet, B2 and abort quadrupole magnets must track the FMI ramp in order to abort the beam at any energy. This will be accomplished by tailoring the design of the abort line so that all these elements are powered in series with one of the quadrupole busses. Steering adjustments will be made using the separately powered trim coil windings in the Lambertson and C-magnets.

The beam dump will be constructed with a graphite core of length 4.4 m, similar to the existing Main Ring beam dump. The kicker power supplies will be located in the MI-40 service building, which will be situated so that relatively short cables (<25 m) can be used between pulsing units and kicker magnets. This is crucial for maintaining the kicker pulse shape. The beam dump will be located approximately 70 m downstream of the end of the MI-40 straight section; at this location, the beam dump will be about 6 m outside of the tunnel, in the vicinity of quad 409.

2.11 Slow Extraction

The slow extraction system has been designed to provide 120 GeV/c resonant extracted beam with a uniform spill over times of one second with losses of less than 1%. Slow spill of the entire beam is easily achieved with half-integer extraction. Extraction is implemented by using special quadrupoles and octupoles to bring the beam onto the half-integer resonance in such a manner that the amplitude of betatron oscillations will grow in a controlled fashion until the particles are deflected by an electrostatic septum. The kick supplied by the electrostatic septum provides enough space between the circulating beam and the extracted beam to allow magnetic septa to be used to extract the beam.

Septa

The extraction septa are located in straight section MI-52. This region must accommodate transfers of 8 GeV, 120 GeV and 150 GeV beams. The geometry of the Lambertson and C-magnets is identical to that of the abort, except the bend of the Lambertsons is vertically upwards. For 8 GeV transfers, only the second Lambertson is excited.

The placement of the electrostatic septum is made easy by the fact that the straight section has sufficient phase advance that both the septum and extraction kicker magnets can be placed within the straight section. It is desirable to have a separation of 6 mm at the magnetic septa between the circulating beam and the extracted beam. A 135 μr kick from the electrostatic septum will achieve this with an applied voltage gradient of 44 kV/cm.

Harmonic Elements

The appropriate harmonics for quadrupoles (53rd) and octupoles (0th) will be provided by recycled Main Ring trim quads and octupoles. The harmonic quadrupoles are distributed around the ring in two families of ten quads each. The orthogonality of these families provides the capability both to cancel the natural half-integer stopband of the machine and to manipulate the orientation of the phase space at the septum during slow extraction. A harmonic octupole is situated at every harmonic quadrupole location. For resonant extraction the harmonic octupole circuit is augmented by the (large) octupole component of the 128 Main Ring quadrupoles in the ring. At all other times the harmonic octupole circuit will be used to cancel this detuning influence of the Main Ring quads. The total strength required of the quadrupoles is 20 kG-m/m and 10^4 kG-m/m^3 for the octupoles.

Phase Space

Extraction starts by raising the normal horizontal tune from 26.4 towards 26.5, while turning on the 0th harmonic octupoles. The octupoles provide an amplitude-dependent tune; thus, larger amplitude particles have a higher tune and are closer to the half-integer. One of the 53rd harmonic quadrupole circuits is then used to increase the width of the half-integer stopband. Small amplitude (smaller tune) particles are stable while larger amplitude particles stream out along the separatrix until they encounter the electrostatic septum. Phase space distributions produced by these elements at the electrostatic septum and at the magnetic septa are shown in Figure 2-12. The rough angle of 45° exhibited by the beam is a compromise between high extraction efficiency (where the angle would be zero) and aperture considerations at the location of the magnetic septa. For the extracted phase space shown, the emittance is 6π with an extraction inefficiency of 1%.

Quadrupole Extraction Regulator System (QXR)

The goal of the slow extraction system is to provide a constant rate of extraction during the slow spill. This is accomplished by moving the stopband

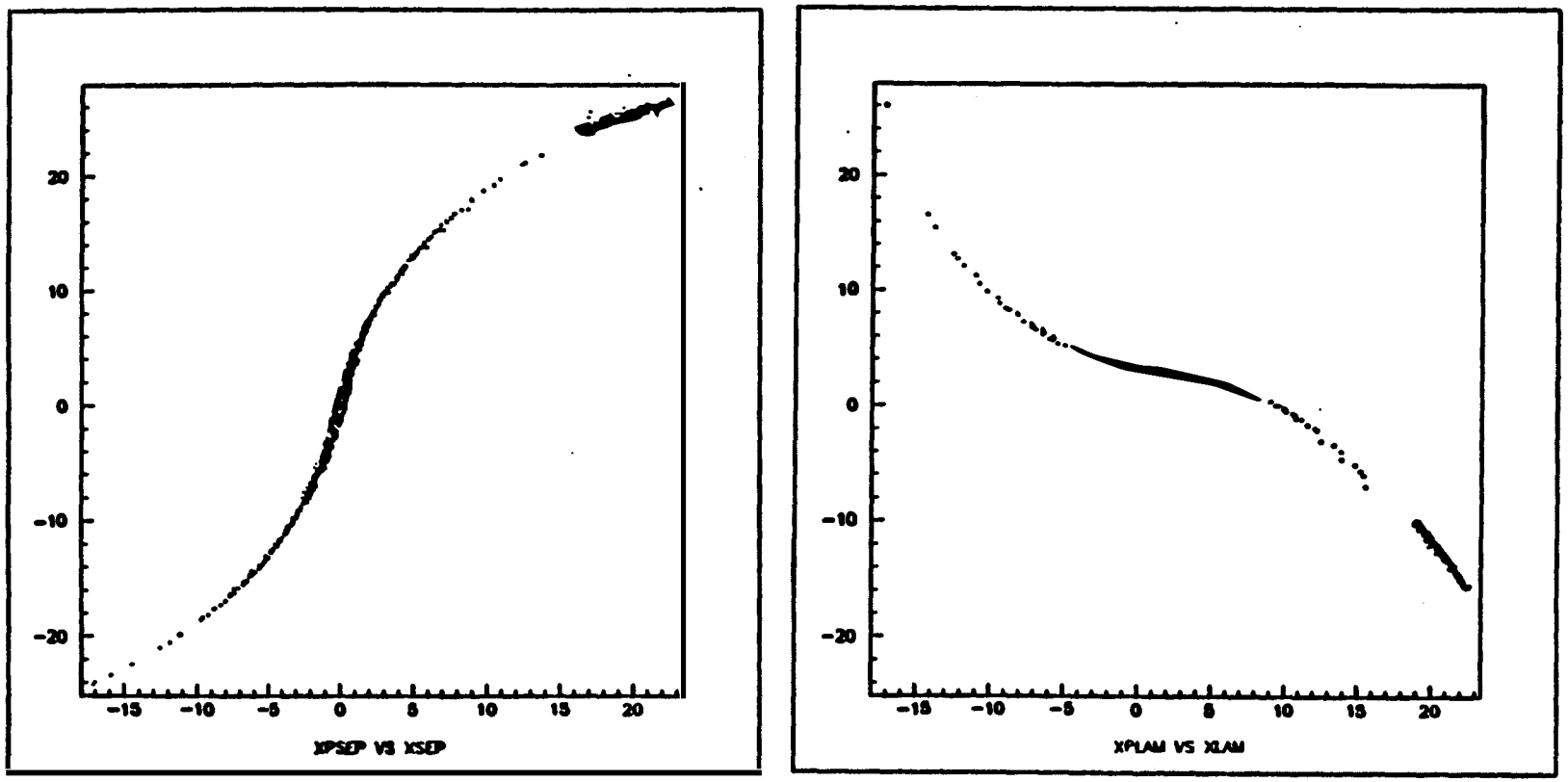


Figure 2-12. Phase space distributions at the electrostatic septum (left) at the extraction Lambertson (right) during slow extraction.

smoothly through the beam using the quadrupole extraction regulator system, QXR. There are two parts to this system, distinguished by strength and bandwidth. The stronger, lower bandwidth components are tied to a normal beam intensity monitor which is insensitive to fast fluctuations. After the signal is sampled during the spill and compared to an ideal signal, the resultant smoothed error signal is used to modify the power supply output. This system is the base from which the weaker, faster responding system works. Monitoring is based on a fast reacting detector in the extracted beamline itself. Power supply ripple up to 360 Hz can be compensated by this system.

2.12 Environmental and Shielding Considerations

The proposed construction of the FMI lies in approximately 400 acres southwest of the existing Main Ring tunnel, between the F0 building (MRRF/TEVRF) and the site boundary. Access to the construction project will be via the existing Kautz Road. Efforts will be made throughout the construction period to protect and enhance the local conditions. Both an Environmental Assessment (EA), which proposes and justifies the publication of a Finding of No Significant Impact (FONSI), and a Preliminary Project Safety Analysis Review (PSAR) have been prepared and submitted to the DOE, and are hereby cited as references in this discussion in the current CDR. These documents replace the appendixes inserted in previous editions of the FMI CDR. Also, an Army Corps of Engineers permit for wetlands and floodplain mitigation has been issued to the DOE for this project.

During the first half of calendar 1991, the Fermilab Accelerator Division completed an extensive and complete review of radiation shielding for the entire accelerator complex at Fermilab. A parallel effort was completed for the extracted beamlines and associated areas managed by the Research Division at Fermilab. For the purposes of this review, management of these two Divisions, in consultation with the Fermilab ES&H Section and the Laboratory Directorate, have created more restrictive definitions of the "accident conditions" for which shielding must be provided.

To be slightly more specific, a shielding assessment for an accelerator at Fermilab is dependent upon three independent pieces of information. The first is the penetration power (measured in earth equivalent) of a particular energetic particle. This is a measurable (and calculable) result. The second is the definition of exposure for both occupational workers and members of the general public. This definition, which includes considerations of the equivalency of various degrees of protection, is contained in the Fermilab Radiation Safety Guidelines. Also contained as part of this definition are the types of exposure to be permitted for both normal and accidental losses. The third consideration is the definition of the source and duration of accidental losses.

The 1991 laboratory-wide shielding assessment did not involve any alteration of the first 2 items discussed above. The Accelerator Division, however, decided to make the most conservative estimate of shielding possible. Therefore, except in cases where accident conditions CANNOT persist continuously (e.g. the Tevatron will quench under loss conditions and take a long time to recover), it is now assumed that accident conditions might persist indefinitely and that shielding and/or active interlock protection must be provided to prevent exposures to workers, or the general public, under these very conservative considerations. This change of the definition of accident conditions and especially the consideration in most instances of an indefinite duration, did lead to an increase in earth equivalent shielding requirements for the existing accelerator complex. In those places where the now required earth equivalent was found not to exist, mitigations in the form of either increased passive shielding, or increased exclusion (fences, etc.) or interlocked detectors to inhibit accelerated beam were introduced. Also, where possible, the goal of achieving unlimited occupancy was pursued.

The shielding criteria for the FMI have been reviewed for the CDR in view of the 1991 shielding assessments discussed above. It has been found that for the FMI, unlimited occupancy for both the FMI service buildings and for outside areas may be achieved in almost all cases. For the design intensity of the FMI, the required shielding for unlimited occupancy is 24.5' of earth equivalent for circulating beam inside magnets in the enclosure. The shielding required for all other configurations throughout the FMI project has been calculated and published for civil designers. Several design alterations have been made for this CDR to reflect the more conservative shielding approach reflected in the 1991 assessment. These include the removal of the FMI service buildings from on top of the accelerator enclosure, and the redesign of the shielding for the preserved MRRF building at FO. Some areas, such as the 120 GeV transport line through the existing Main Ring F-Sector for extracted FMI fixed target beam, may not achieve the shielding requirements solely by the addition of passive shielding, but the mitigations in these areas will be consistent with the evaluation procedures used for the 1991 assessment.

Calculations have been made of radiation dose near the tunnel when beam is lost on the magnets or dumped intentionally. These calculations are consistent with the shielding of 24.5' of earth equivalent for unlimited occupancy as mentioned above. The dose is estimated both on the earth berm covering the tunnel and at the site boundary at the point of closest approach (approximately 75 m) to the FMI. The integrated levels from any continuous loss of beam is less than the 500 mR/yr limit for permanent occupancy. The off-site dose is at least a factor of 5 below the required limit of 10 mR/year. Attention has been given to the particular problems associated with the culverts crossing over the FMI ring, and the radiation at those points has been reduced to acceptable levels. The dose rate in the vicinity of the abort dump (Section 2.10) has been investigated and found to be lower than required.

For accidents originating in the plane of the FMI magnets, the highest muon dose is only 0.3 mR and occurs about 70 m downstream of the loss point, if one assumes that the berm meets grade level at that point about 10' above the center of the tunnel. In most cases, grade level is higher than this, but the highest muon dose is not significantly affected, although the location of emerging muons relative to the berm may be altered. For accidents originating in the rising sections of the 120 GeV/150 GeV transfer lines, muons associated with hadron showers will be more directed toward the surface. Considering that earth equivalent shielding is of only modest utility for muon shielding, the locations of the emerging showers may be locally enclosed with fencing, since they will be very restricted in extent. The exact location and extent of these regions containing 'rising muon showers' will only be defined when the final transport line configurations are complete in detail. The nature of the problem, however, is similar to that found on the rising arc of the Main Ring overpasses at the collider detectors at present. The problem at those Main Ring locations has been considered in the 1991 shielding assessment and is not severe, indicating that it is possible that while the muon dose rate from accidents in the rising transport lines may exceed that accepted for unlimited occupancy, it may be consistent with minimal occupancy which would not even require fencing. Calculations will be made.

2.13 Utilities

FMI Low Conductivity Water System and Magnet Bus Connections

The proposed system for connecting the power and water to the FMI is similar to the Main Ring. This system requires minimum maintenance. Stainless steel headers supply low conductivity water (LCW) to copper pipes which conduct both power and cooling water to the magnets. Ceramic feedthroughs, with flexible metal braid hoses, electrically insulate the piping from the copper bus system. All connections are either brazed or welded.

The FMI components and associated utilities are grouped together at the outside wall of the tunnel leaving most of the enclosure space for servicing, as shown in Figure 2-13. All connections to the magnets are designed so they are accessible from the inner space of the tunnel. There will be six utility buildings uniformly spaced along the perimeter of the FMI. These are labelled MI-10, 20, 30, 40, 50, and 60. Each utility building will supply power and cooling water to about 1,815 feet of circumference in the FMI.

Four service building will have three pumps each, and the remaining two buildings will have four pumps all connected in parallel. Each pump has a 50 hp motor, and delivers 300 gpm of LCW with a pressure head of 162 psi (375 TDH). The heat from the magnets is transferred to the LCW and dissipated in a tube and shell heat exchanger placed above the pumps in each service building. Pond water is circulated in the tube side of the heat exchanger to remove the heat by evaporation.

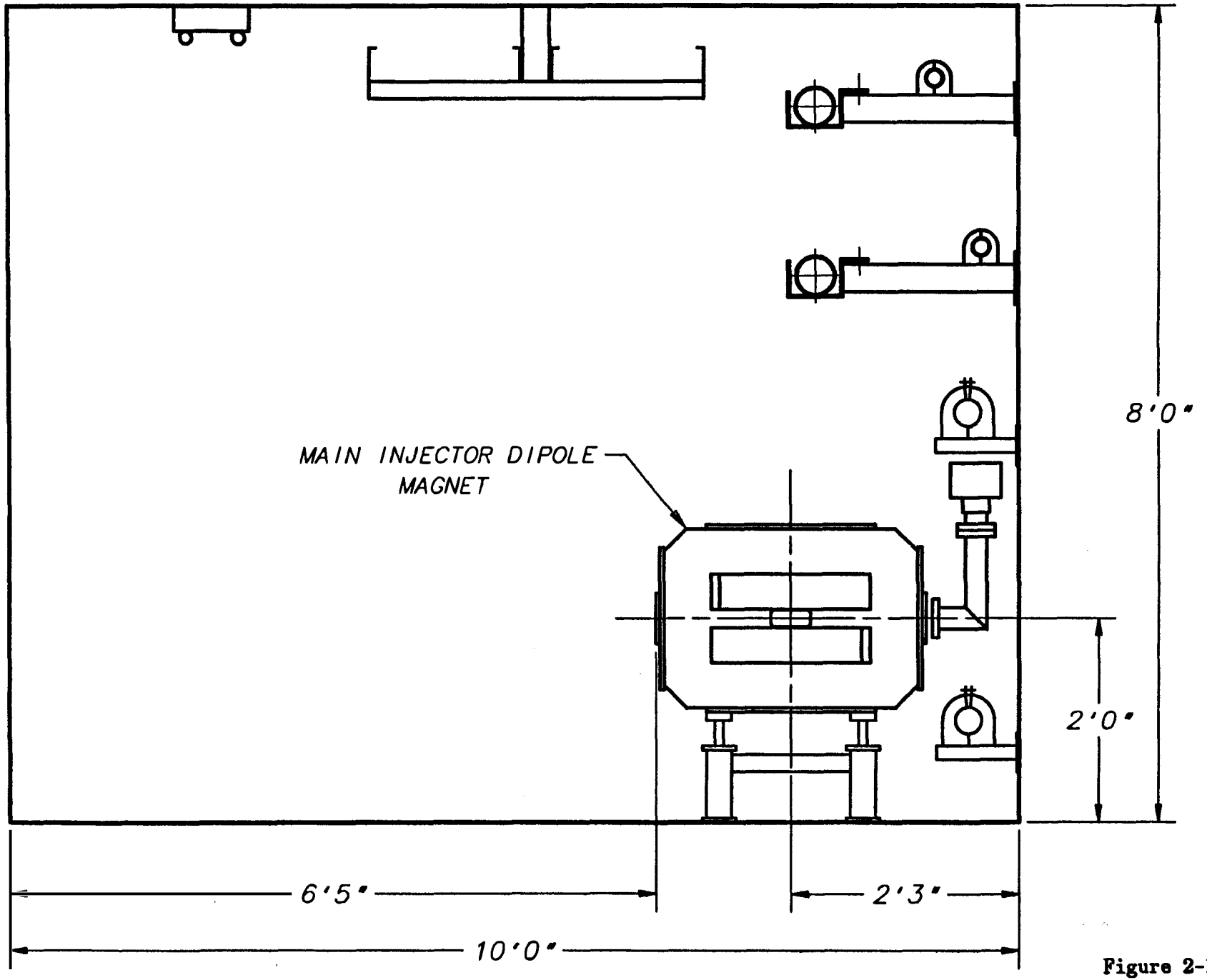


Figure 2-13.

From the existing LCW system in the Main Ring, 12 pumps with starters and controllers, and six heat exchangers will be reused for the FMI. Seven existing spare pumps will also be used, and one new pump will be required. The remaining water cooling equipment in the Main Ring will remain as part of the Tevatron. New extra strong copper bus (2.875" o.d. by 1.771" i.d. for the dipoles, and 2.00" o.d. by 1.2" i.d. for the quadrupoles) will be used for the FMI. The old copper bus from the Main Ring (1.625" o.d. by 0.187" wall) with the porcelain clamps will be reused for the beamlines.

Two 4" stainless steel pipe headers will be installed over the magnets along the 10,891' circumference of the FMI. A total of 20 pumps (300 gpm each) will be connected in parallel across the supply and return pipes. All magnet and bus systems will also be connected in parallel across the LCW headers. For 120 GeV operation (5,000 amps rms), the water temperature rise across the magnets is calculated to reach about 7°C. An average of 950 gpm of LCW from each of the six service buildings will be required to cool magnets, bus, power supplies, chokes, and electronics equipment. The heat load removing capacity per building is about 2 MW limited by the cooling pond.

At each utility entrance, as well as at locations half-way in-between, the enclosure will have a ceiling one foot higher than the regular tunnel. The purpose of this extra space is to make room for expansion joints for the 4" stainless steel pipes, copper bus, and trays. At this position the enlarged enclosure allows the utilities to cross over without obstructing the regular tunnel clearance for the magnet moving vehicle.

A net counterclockwise flow in the ring will be accomplished with restricting valves at each of the entrances. In each service building around the ring, portable mixed-bed deionizer bottles will be installed. A continuous polishing flow of about 30 gpm per service will be required to keep low conductivity in the water. The bottles are only used for polishing action. An average of 9 MΩ-cm resistivity of the LCW will be maintained in the ring. LCW fills will be done from the Central Utility Building (CUB) via the 8 GeV line. There we have large industrial deionizer columns with the appropriate EPA guidelines for the effluent discharge system. The portable deionizer bottles will be regenerated in the CUB with the existing regeneration system. In service building MI-60, a 3,000 gallon combination storage and expansion tank will be installed for emergency LCW make-up. The FMI will require an estimated 29,000 gallons of LCW to fill the pipes, tanks, bus, and magnets.

Power Distribution for the FMI

There are three separate power systems associated with the FMI system: 1) power system for pulsed power supplies; 2) conventional power system; and 3) power system for beamlines. The power distribution system is shown schematically in Figures CDR-28 and -29 (Appendix E).

Power System for Pulsed Power Supplies

This system consists of two new 40 MVA transformers at the Kautz Road Substation and a new 13.8 kV distribution system to the FMI. A 13.8 kV switchgear area, located near the MI-50 service building, allows sectionalizing of the system. From this switchgear, three loop feeders, situated within a ductbank, are used for the pulsed power to the ring.

At each service building, there is a disconnect switch to supply power to the power supplies. From the disconnect switch to the power supply transformers, the feeders are routed in a ductbank. Paralleling switches at the south side of the ring enable uneven loading of each segment without overloading the feeders. These switches can also be used for feeder isolation for maintenance purpose.

Each feeder consists of three 750 MCM aluminum 15 kV power cables, each 2,000' long so that no splices are needed between service buildings. Feeder construction will be cross-linked polyethylene, concentric neutral with overall jacket.

Two harmonic filters will be installed at the MI-50 switchgear area to prevent possible component damage due to excessive harmonic distortion caused by the power supplies. One of the filters will re-use the existing components from the present Main Ring pulsed power distribution system. The second filter will consist of newly procured components.

Conventional Power System for the FMI

This system will consist of one 13.8 kV feeder around the FMI ring with a 500 kVA transformer at MI-10, MI-20, MI-30, MI-40, MI-50, MI-52, and MI-62, a 750 kVA transformer at the 8 GeV service building and a 1,500 kVA transformer at MI-60 service building. The conventional power will be used for smaller power supplies, building power, lights, pumps, etc. Power is derived from the existing 82B transformer relocated to the Kautz Road Substation. At each service building there will be a disconnect switch between the ductbank connection and the 500/750/1,500 kVA conventional power transformer.

The feeder will consist of three 750 MCM aluminum 15 kV power cables, each a maximum of 2,000' long so that no splices are needed between service buildings. Feeder construction will be cross-linked polyethylene, concentric neutral with overall jacket.

Power for Beamlines/RF

This system consists of a 40 MVA transformer at the Kautz Road Substation and 13.8 kV feeders to the beamlines and rf at MI-60. Power is delivered to the 8 GeV beamline through the FMI ductbank to the 8 GeV service building. All other beamlines will be fed via a new ductbank from the Kautz Road Substation to the existing Main Ring ductbank at E3. This feeder will stop at

F0, F1, F2, F3 and F4. Power for the rf systems will be delivered to the MI-60 building via a feeder in the FMI ductbank.

Each feeder consists of three 750 MCM aluminum 15 kV power cables. Feeder construction will be cross-linked polyethylene, concentric neutral with overall jacket.

The ductbank between Kautz Road Substation and the Main Ring ductbank at E3 will also function as the cross connect between the existing Master Substation and Kautz Road Substation. This cross connect will allow the transfer of 40 MVA during routine maintenance and failures at either substation.

3. BEAMLINES AND BEAM TRANSFERS

Five new beamlines with a combined length of about 1,400 m are required to integrate the FMI into the existing Fermilab accelerator complex:

1. A 760-m beamline for transport of 8.9 GeV/c protons from the Booster (straight section L3) to the FMI (MI-10 straight section) for injection.

2. A 260-m Tevatron injection beamline which transports 150 GeV/c protons from MI-52 straight section in the FMI to the Tevatron (TEV-60).

3. A 260-m beamline which transports 150 GeV/c antiprotons from MI-62 straight section in the FMI to the Tevatron (TEV-60).

To link the new FMI complex to the Antiproton Source and Switchyard, the existing magnets and power supplies in F-Sector (from F0 to A0) of the Main Ring and of AP1 will for the most part remain in place. The 150 GeV/c line from MI-52 will provide the link between the FMI and the F-Sector magnet string of the Main Ring. This is made possible because the Lambertsons used for Tevatron injection will act as a magnetic switch for selecting either the Tevatron or Main Ring F-Sector. Figure 3.1 shows an elevation view of the Tevatron F0 straight section.

4. A 15-m section of magnets used to match between the Tevatron injection Lambertsons and Main Ring station F-11.

The 120 GeV protons used for antiproton production will be transferred at Main Ring station F17 into the existing AP1 beamline. This section of beamline will also be used to transfer 8.9 GeV/c antiprotons from the Antiproton Source to the FMI station MI-52 for injection into the FMI. The 120 GeV/c protons used for the "test beam" are transported through the entire F-Sector to A0 where the fifth beamline is to be installed.

5. A 130-meter section which connects F49 to the upstream end of Switchyard.

The site coordinates of all beamline elements have been determined and the beamline layout is shown in Figure CDR-10 (Appendix E). Optical designs exist for the 8.9 GeV/c Booster to FMI line, the two 150 GeV/c FMI to Tevatron beamlines, and the FMI to Main Ring F11 beamlines. Longitudinal beamline sections showing the disposition of the elements within the beam transfer lines are shown in Figures CDR-13 to CDR-18. These sections are of the previous design and are considered obsolete. They will be modified during Title I.

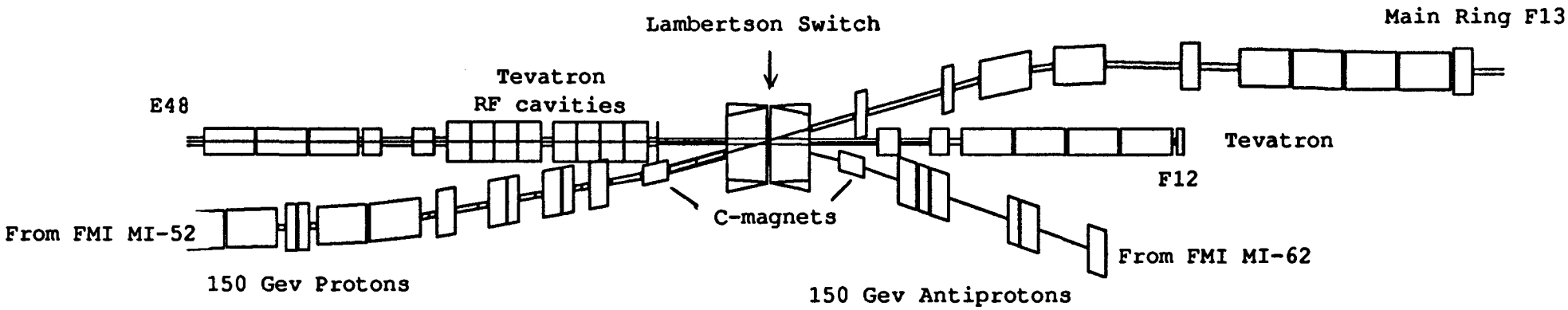


Figure 3-1. Elevation view of Tevatron F0 straight section.

3.1 The 8 GeV Line

The 8 GeV line is comprised of four major sections: a matching section between the Booster and the main body of the beamline; descent from the Booster to FMI elevation; a long section of periodic FODO cells; and a final matching section into the FMI. Design of the 8 GeV line is driven both by the desire to optimize utilization of recycled Main Ring magnets and to minimize the impact of the line on existing roads and structures.

Protons are extracted horizontally from the Booster at straight section L3. Two EPB dipoles centered 10.6 m downstream of the extraction point provide 9.37° of horizontal bend to steer the beam into the existing AP-4 enclosure. A third EPB, centered 18.2 m further downstream, bends the beam through 4.64° to put it on a line parallel to, and 2'6" away from, the wall of the enclosure. The line extends another 34.4 m to the end of the existing enclosure. Two SDB dipoles, separated by 26.7 m, then provide 11.0° of bend each to steer the beam sharply away from the existing AP-4 line's trajectory. This completes the Booster matching section.

Immediately following this matching section a recycled Main Ring B3 dipole pitches the beam downwards by 3.0°. Once the 10'9" corresponding to the Booster-FMI elevation difference is obtained, another Main Ring B3 cancels the beam's downward pitch. The 360° of betatron phase advance of this special insert section ensures that the vertical drop is achromatic, with vertical dispersion not exceeding 0.70 m.

One hundred and twelve degrees (112°) of horizontal bend are achieved in the next 555 m of the line by 51 recycled Main Ring B2/B3 dipoles embedded in a regular 90° FODO lattice. The trajectory of the line through this section takes the protons 10'9" below the existing AP-2/AP-3 enclosure, or 16'9" below the AP-2/AP-3 beamlines. The line never approaches the Tevatron closer than approximately 100'. The final 2° of horizontal bend from the recycled A0 Lambertson places the protons on the horizontal closed orbit of the FMI. The 8 GeV proton line terminates at the D quad (quad 101) 17 m upstream of the MI-10 straight section center.

The lattice functions for the 8 GeV line are illustrated in Figure 3-2. Horizontal dispersion does not exceed 3.12 m through the arcs. With the choice of a 51.0 m maximum beta in the FODO cells, the transverse beam size is less than ±16 mm for a normalized transverse emittance of 40π mm-mr and $\Delta p/p$ of 0.002. With each dipole producing a bend of 2.20° the sagitta is only 1.15", which is perfectly acceptable.

<u>FMI Injection</u>

Injection of 8.9 GeV/c protons is accomplished in the FMI straight section MI-10. The straight section is approximately 69 m long and has to

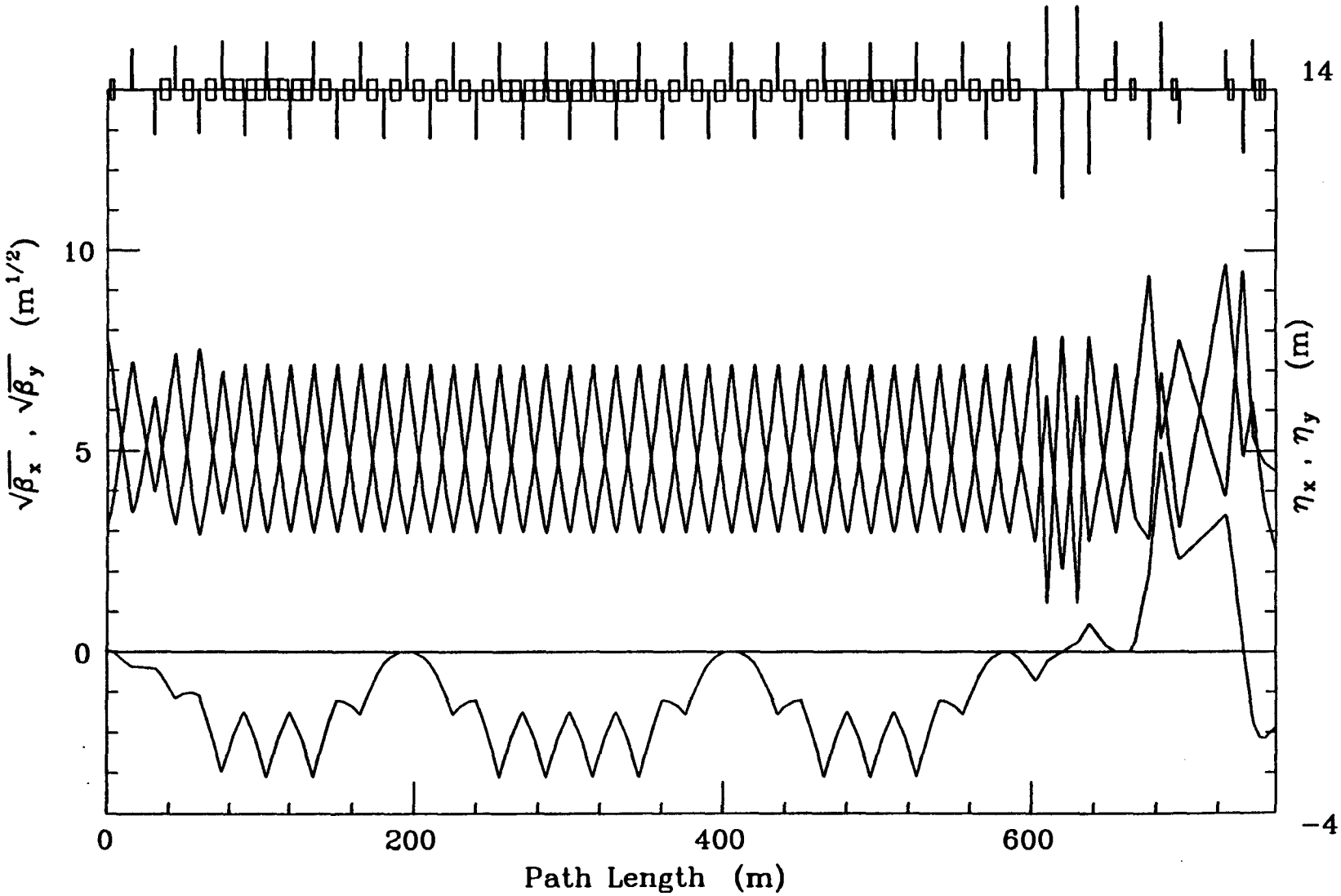


Figure 3-2. 8 GeV Line lattice functions.

accommodate the horizontal injection Lambertson and vertical kickers. The Lambertson is located at the D quad 17 m upstream of the straight section center; this quadrupole must be rotated by 90° to provide adequate vertical aperture for the injected beam. The beam trajectory in the horizontal plane at the entrance to the Lambertson is displaced 38.9 mm from center with a 34 mrad angle. Vertically the beam is 40 mm above the center of the aperture; the FMI circulating beam is displaced 10 mm downwards. The Lambertson removes the 34 mrad angle to bring the beam onto the horizontal closed orbit of the FMI. Figure 3-3 shows the Lambertson and quadrupole magnet apertures and 40π mm-mr beam profiles at 8 GeV and 150 GeV.

Four vertical kicker modules located 90° downstream of the Lambertson remove the vertical offset present at the Lambertson to place the injected protons onto the vertical closed orbit of the FMI.

No other magnetic elements are required for the injection of 8.9 GeV/c protons. The injection of 8.9 GeV/c antiprotons from the Accumulator takes place in straight section MI-52 which is also used for extraction as discussed in Section 3.3. The antiproton injection process uses the same vertical Lambertson and horizontal kicker which are used for proton extraction.

3.2 The 150 GeV Lines

Two beamlines connect the FMI to the Tevatron. One of these simply provides transport of the 150 GeV/c antiprotons. The other, in addition to delivering 150 GeV/c protons to the Tevatron, must transport 120 GeV/c protons destined for the antiproton target or Switchyard and 8.9 GeV/c antiprotons destined for injection into the FMI. These additional functions are described in the following sections; here are described only the two optically similar beamlines which transport particles from the FMI to the Tevatron. The difference between the proton and antiproton transfer lines originates in the slight asymmetry of the injection point in the Tevatron with respect to the two particles: the two beamlines must match into different lattice functions.

The elevation of the FMI is 2.332 m below the Tevatron. Protons (antiprotons) are extracted by kicker magnets which deflect the beam across the septa of vertically bending Lambertson magnets located in the MI-52 (MI-62) straight section. A C-magnet (current septum magnet) follows the second Lambertson. The Lambertson and C-magnets deflect the beam upward by 24 mr and are followed by three vertical C-magnets which reduce the vertical pitch to 3 mr. The horizontal dipoles are rolled to produce the desired horizontal and vertical trajectory for vertical injection into the Tevatron. The total beamline length is 260 meters. Each of the lines include 15 recycled 6-m Main Ring B2 dipoles and 14 quadrupole elements, composed of 17 recycle Main Ring quads. The five vertical C-magnets and the three Lambertson septum magnets will be constructed based on a current Fermilab design.

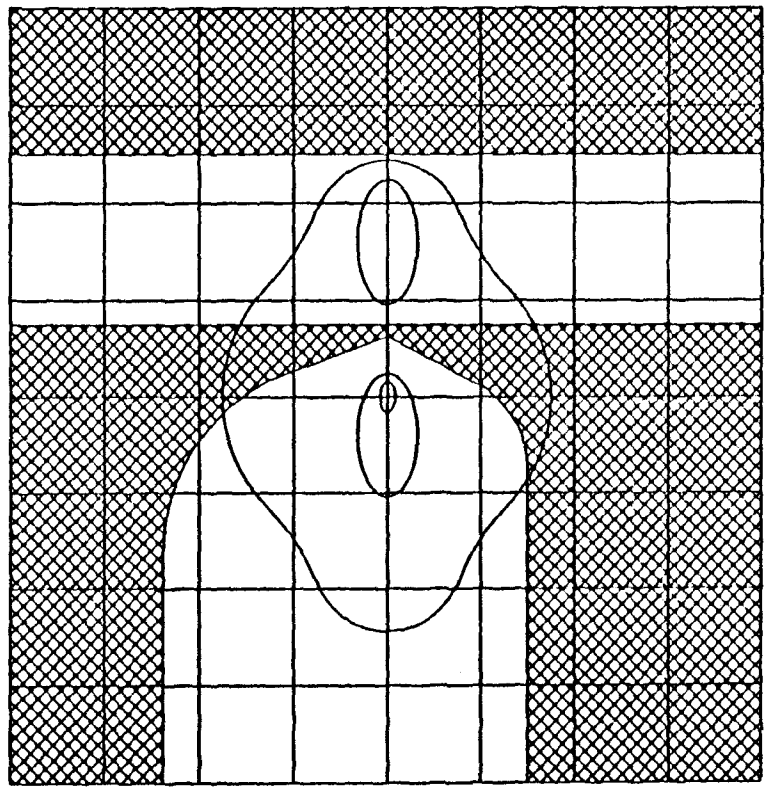


Figure 3.3. Profiles at the injection Lambertson and quadrupole.

The lattice functions for the 150 GeV/c Tevatron injection lines for protons and antiprotons are shown in Figures 3-4 and 3-5. The current optical solutions have all eight lattice functions well matched to the Tevatron. Both transport lines have an identical design with the exception of minor differences in the location and gradient of the last four quads in each line to accommodate the match into the optically asymmetric Tevatron F0 straight section. The lines basically consist of continuing the cell structure of the FMI lattice to a pair of doublets used for matching into the Tevatron. The vertical dispersion generated by the vertical extraction components is almost canceled by the vertical injection magnets. To complete the cancellation and satisfy the extremely tight geometrical constraints four families of rolled dipoles were utilized.

FMI Extraction

Extraction takes place at the two long straight sections near Tevatron straight section F0: MI-52 (proton extraction) and MI-62 (antiproton extraction). Figure 2-4 shows a plan view of long straight MI-52 and the beginning of the extraction line.

Transfer is initiated by a kicker (or electrostatic septum in the case of slow extracted protons) located 90° upstream of the Lambertson septum magnets. The kicker displaces the beam horizontally across the Lambertson septa; the Lambertson and C-magnets deflect the extracted beam upward by 24 mr for both transport lines. The 24 mr angle is the minimum required for just clearing the top of the FMI quadrupole at the end of the long straight section.

The requirements on the proton extraction Lambertson aperture are dictated not by the 150 GeV/c extraction, but by its use as the injection Lambertson for 8.9 GeV/c antiprotons. Thus a Lambertson magnet of the "F17 style" design will be used at MI-52. This is the magnet currently used for injection of 8.9 GeV/c antiprotons into the Main Ring. With the reduced β functions at the straight section, the aperture is sufficient for the acceptance of 40π mm-mr antiproton beams from the Antiproton Source. The Lambertson magnets are the same type as those used for the abort in MI-40. Figure 3-6a shows the Lambertson and quadrupole magnet apertures and 40π mm-mr beam profiles at 8.9 GeV/c and 150 GeV/c. Generous clearance for the injected and circulating beams is afforded. Only the second Lambertson magnet is excited for 8.9 GeV/c beam transfers, so the beam passes through the quadrupole with no vertical offset. Figure 3-6b shows the magnet aperture and beam size at the entrance to the C-magnet.

Tevatron Injection

Injection into the Tevatron is moved from its present location in the E0 straight section to the F0 straight section. This move leaves the E0 straight section completely free for possible use as an interaction region or for other purposes.

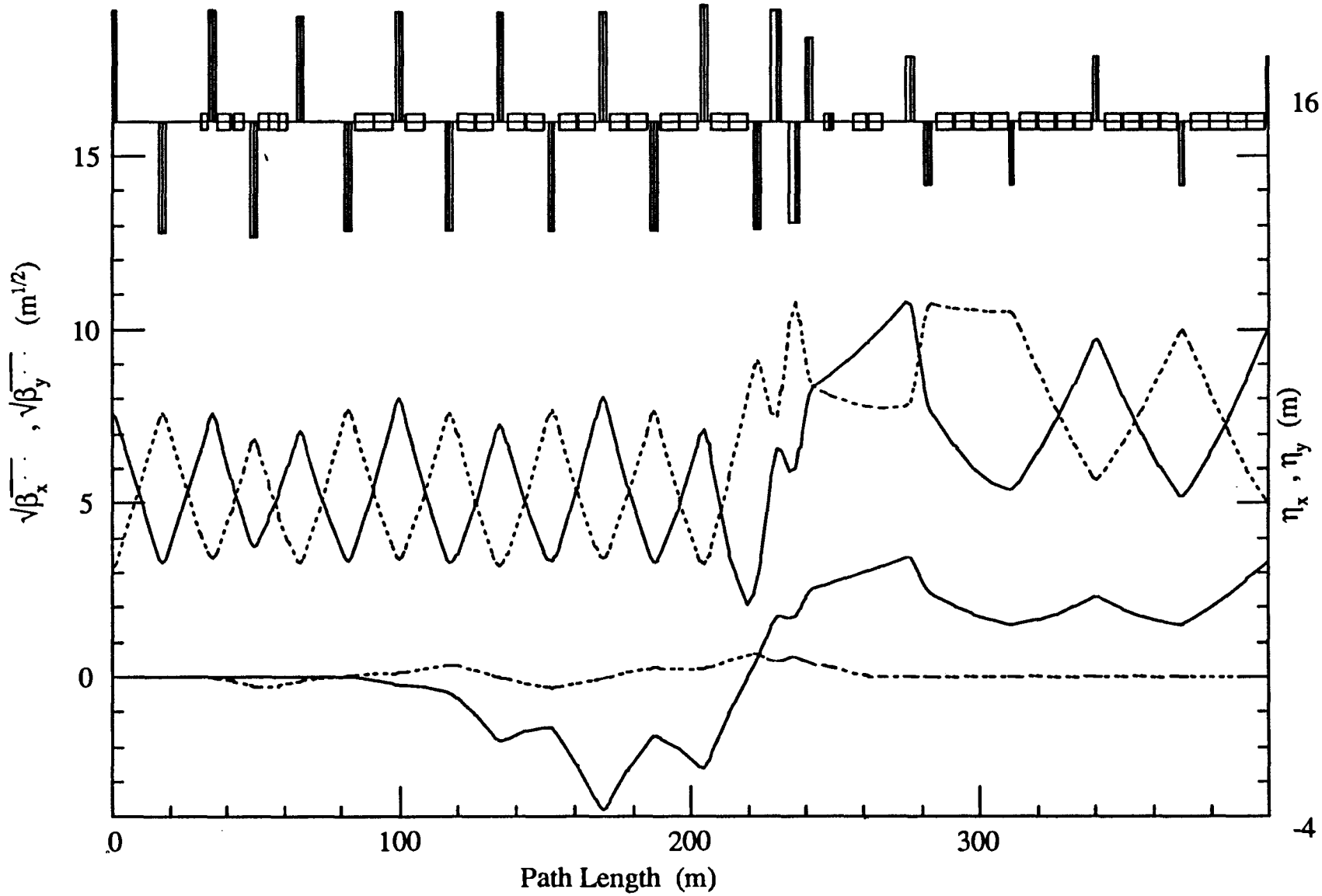


Figure 3-4. 150 GeV proton beamline and lattice functions.

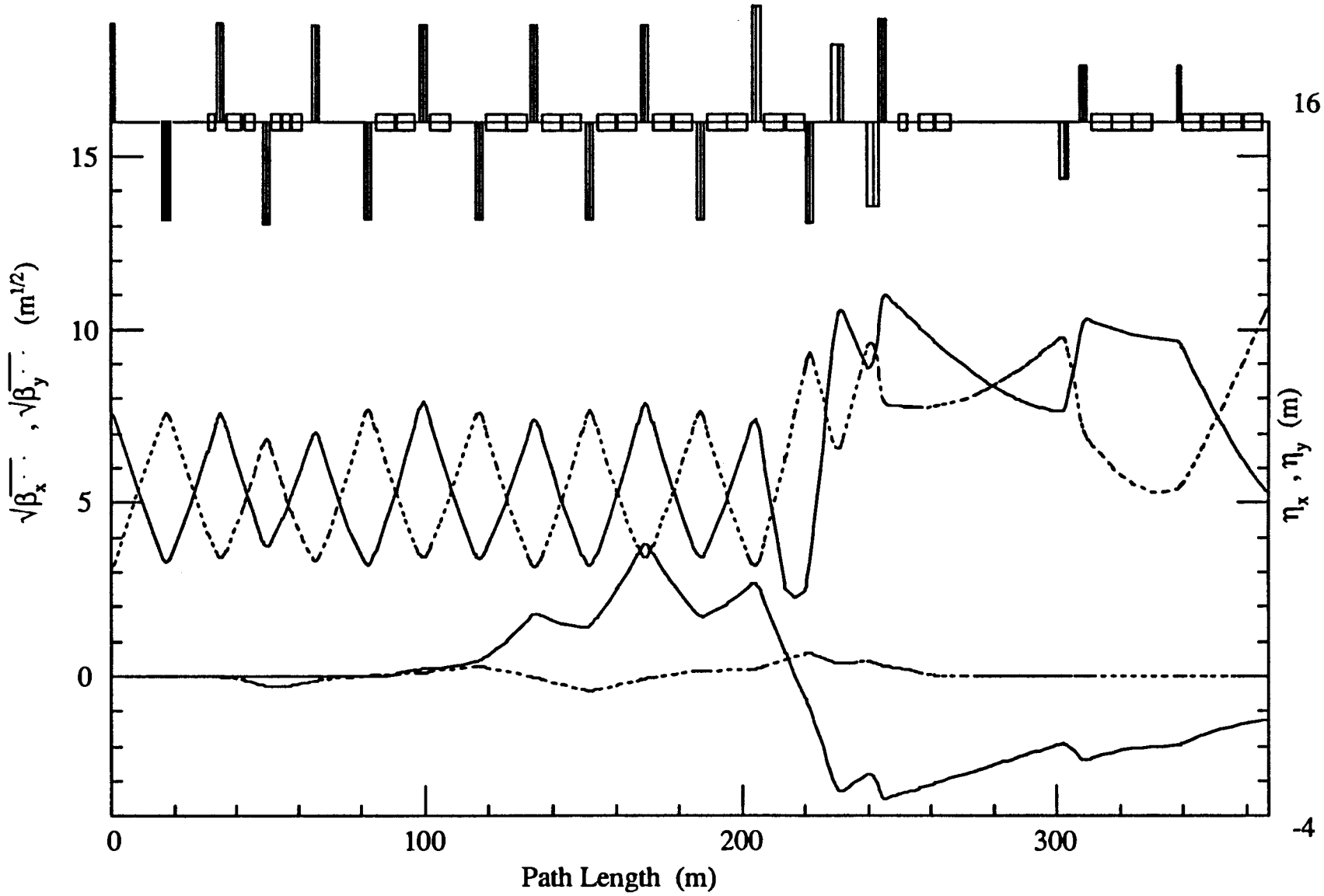


Figure 3-5. 150 GeV antiproton beamline and lattice functions.

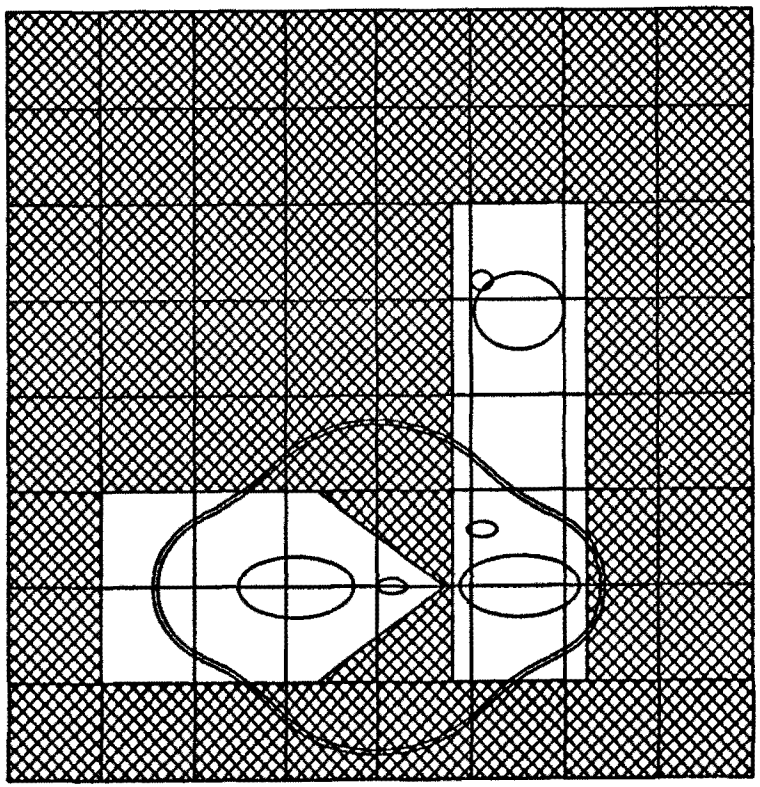


Figure 3-6a.
Profiles at the Extraction Lambertson
and the Adjacent Quadrupole

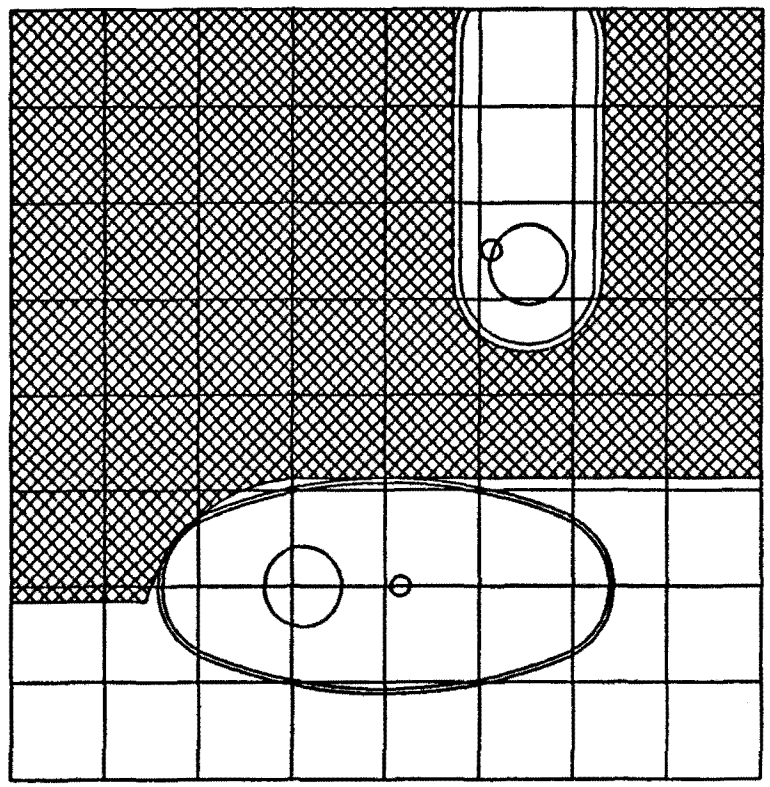


Figure 3-6b.
Profiles at the Entrance to the C-magnet

The F0 region will continue to be used to accomodate the Tevatron rf systems. By rearranging the accelerating cavities in the upstream end (proton beam direction) of the straight section, the proton and antiproton injection lines can converge toward a common set of injection septum magnets located at the downstream end of the straight section. This reduces the number of such elements needed for injection into the Tevatron. In the present Tevatron, the accelerating cavities are arranged in a manner such as to ensure proper phasing between the proton and antiproton systems and to minimize the effects of cavity trips. Thus, a new layout of the cavities is necessary and its consequences must be investigated.

The present injection scheme into the Tevatron is one in which the incoming beam approaches the accelerator vertically. This injection scheme is maintained in the current design where the last vertical bend is produced by a pair of Lambertsons common to both proton and antiproton injection lines. The closure onto the horizontal orbit being produced by a kicker magnet downstream of the injection point. The nearest points on either side of the long straight section where kickers may be placed are the F17 medium straight section (for clockwise proton injection) and the E48 short straight section (for counterclockwise antiproton injection). The present kickers for proton (antiproton) injection into the Tevatron will be recycled.

Injection System Layout

The Tevatron rf system occupies roughly 26 m of the 52 m straight section. In the remaining 26 m, two Lambertson magnetic septa are placed symmetrically about a point 13 m upstream (proton direction) of the end of the straight section. Both the proton and antiproton beams pass through the field region of these magnets upon injection. With the Lambertson off, the 120 GeV/c protons and the 8.9 GeV/c antiprotons will pass through the same field region (de-energized) to get to/from the Main Ring remnant. To accommodate the 120 GeV/c proton and the 8.9 GeV/c antiproton trajectories, a Lambertson is being designed with a larger field region. This design is based on the present Fermilab F17 Lambertson design. The same Lambertson design will be used for FMI extraction (proton, antiproton, and abort) discussed earlier. To provide more clearance at the ends of the free space, each of the injection lines incorporates one C-style magnet just in front of the Lambertsons. An elevation view of the F0 region is shown in Figure 3-1.

3.3 120 GeV Antiproton Production

The existing AP-1 beamline, which is used to target 120 GeV/c protons for antiproton production and transport 8.9 GeV/c antiprotons back into the Main Ring, will remain intact. The Main Ring magnets from F11 to F17 will also be used in their present locations, with only minor modifications to the bus and power supplies. The 120 GeV/c protons will utilize the Tevatron proton injection line from the FMI (MI-52) to the Tevatron injection Lambertsons.

With the Lambertsons off, the protons will enter the Main Ring remnant at Main Ring station F11 for transport to Main Ring station F17. A vertically bending Main Ring B-3 dipole, located immediately downstream of the Main Ring F17 quad will, if energized, deflect the beam into the existing AP-1 beamline. De-energized, this magnet will allow the 120 GeV/c slow spill to be transported to the Switchyard. Figure 3-7 shows the retune of the Tevatron proton injection line for matching into the Main Ring remnant.

Modifications to Main Ring F11 to F17 Magnet String

This section of magnets will be used in their current location. Only minor modifications to the magnet bus will be required to power the dipole and quadrupole circuits. The B1 magnets (1.5"x5" beam pipe) will be replaced with B2 magnets (2"x4" beam pipe) to increase the acceptance for antiproton transfers. In addition, it may be determined advantageous to replace the six B2 magnets at the largest vertical β-function locations with B3 magnets (3"x5" beam pipe). The quadrupoles at F11 will be modified to produce a doublet that matches into the Main Ring FODO lattice at Main Ring F13. The four Main Ring F11 dipoles will be replaced by two B3 dipoles running at twice the field of a standard B2 dipole and rolled by about 40°. The Main Ring F12 dipoles are also rolled (with the first dipole being replaced by a B3 at twice the field) to produce the required horizontal and vertical trajectory for the present Main Ring trajectory at F13. A Main Ring power supply located at F1 will be used to power the bending magnets in this section. The focussing and defocussing quadrupole busses will be powered in series by a new supply. The dipole correction elements in this section will remain for use in smoothing the orbit for 8.9 GeV/c antiprotons.

Connection with the Existing AP-1 Beamline

Currently, a kicker at E17 is used to supply the required orbit distortion necessary to place the beam in the field region of a Lambertson magnet at F17. The Lambertson will be replaced by a vertically deflecting B3 to bend the beam up to miss the first downstream Main Ring dipole and enter the AP-1 line. The match between the Main Ring F17 and the AP-1 line will not be altered. The advantage of the B3 magnet is to provide a larger aperture for the 8.9 GeV/c antiprotons. The B3 magnet must be turned off for slow spill to Switchyard. A proposed FMI acceleration cycle which mixes $\bar{p}$ production and slow spill on a common flattop would require a kicker and Lambertson to remain at this location.

3.4 The 120 GeV Slow Spill Line

The 120 GeV slow spill beamline is used to transport slow and fast extracted beam from the FMI to the experimental areas for a variety of purposes during collider and/or fixed target runs. This beamline uses four beamline sections: 1) MI-52 to F11, 2) F11-F17 magnet string, 3) F18-A0 magnet string, and 4) the new section of beamline between F48 and Switchyard.

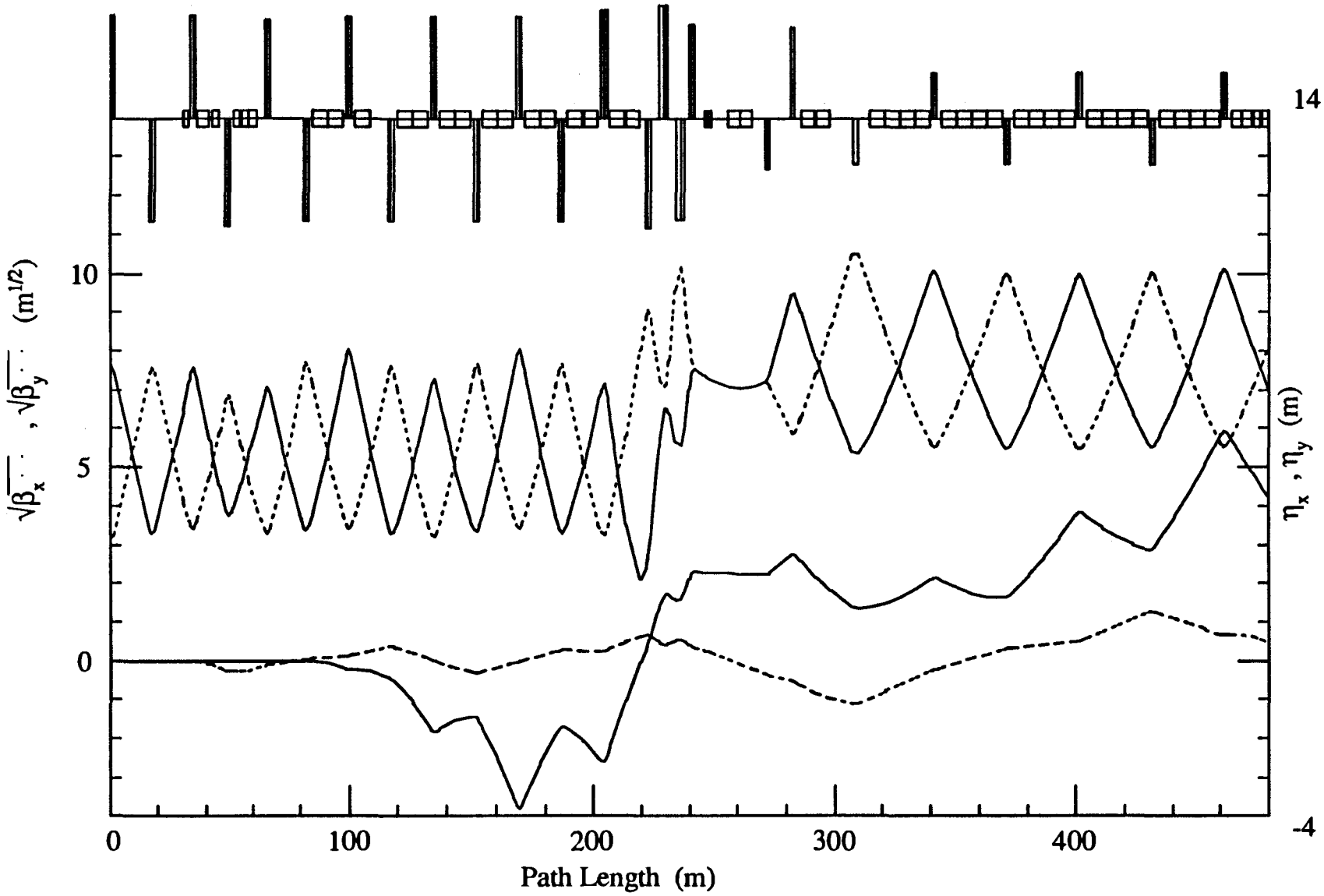


Figure 3-7. Retune of the Tevatron proton injection line for 120 GeV match into MR remnant.

Modifications to F18-A0 Magnet String.

The magnet string will remain in its current location. The fourth Main Ring F47 6-m B2 dipole will be replaced with a rolled (-4.4°) B3 dipole at twice the field. The three Main Ring F48 dipoles will be removed. These modifications will produce a trajectory approximately 3 ft west of the entrance into the Switchyard with a downward pitch. Minor bus work will be needed to connect the four power supplies required to ramp the bending magnets in this section. One Main Ring power supply at F3 will be used to power the two quad busses in series. The quadrupoles at F48 and F49 plus an additional Main Ring recycled quad will be powered individually to produce the required optical match into the Switchyard. A savings in operating cost could be realized by replacing the B2 magnets in this section with B1 magnets, which have a lower impedance.

F49 to Switchyard

A pair of recycled Main Ring B2 horizontal bending dipoles located 60-m downstream of F49 will be powered individually to produce a trajectory which intercepts the Switchyard beamline approximately 40 meters downstream of the present Switchyard channel. The final closure onto the horizontal and vertical Switchyard trajectory is by a rolled (-17°) B3 dipole powered by the F-Sector dipole bus.

Modifications to Switchyard

Minor modifications to the upstream end of the Switchyard are required. The first horizontal dipole and quad along with five of the seven proton electrostatic splitting septa modules PSEPs will be moved upstream. The last two PSEP modules will be shifted downstream to provide space for the rolled B3 magnet used to match into Switchyard. The two PSEP modules downstream of the B3 are required to provide test beams to all areas.

3.5 Beamline Magnets and Power Supplies

Magnet Requirements

Magnet requirements for all beamlines are summarized in Table 3-1. Decommissioning the Main Ring and the 8 GeV line will provide a major source of magnets for the beamlines.

The new 8 GeV line utilizes 51 recycled Main Ring B2 magnets for all the required bends with a few exceptions. All exceptions are located in the upstream end of the beamline. The necessity for the exceptions are generally due to tight spatial constraints (EPBs), required small bend radii (TeV I style SDB dipoles), or large aperture (Main Ring B3s). All quadrupoles in the 8 GeV line are of the SQA type. Seventeen of the 51 required will be recycled from the current 8 GeV line. The remainder will be newly constructed. The Lambertson magnet and power supply currently being used for 8.9 GeV/c proton injection into the Main Ring will be used without any major modifications. The existing injection kicker power supply will be used with minor modifications.

Table 3-1: Beamline Magnet Requirements

	Number	Magnet Style	Status
150 GeV (both)			
Lambertson	6	F17 type	New
C-magnet	10	F17 type	New
Dipoles	30	B2	Exist
Quadrupoles	26	3Q84	Exist
	8	3Q52	Exist
Trims (H)	12	MR trim	Exist
Trims (V)	12	MR trim	Exist
F0/F17 Magnet String			
Dipoles	15	B1/B2	Exist
	8	B3	Exist
Quadrupoles	6	3Q84	Exist
	2	3Q52	Exist
C-magnet	2	F17 type	Exist
Trims (H)	4	MR trim	Exist
Trims (V)	4	MR trim	Exist
F17/SY Magnet String			
Dipoles	101	B1/B2	Exist
	2	B3	Exist
	1	2xB2	Exist
Quadrupoles	27	3Q84	Exist
	4	3Q52	Exist
Trims (H)	14	MR trim	Exist
Trims (V)	14	MR trim	Exist
Abort			
Lambertson	2	F17 type	New
C-magnet	1	F17 type	New
Dipoles	2	B2	Exist
Quadrupoles	3	3Q52	Exist
Trims (H)	2	MR trim	Exist
Trims (V)	2	MR trim	Exist
8 GeV			
Dipoles	51	B2	Exist
	2	B3	Exist
	2	SDB	New
	3	EPB	New
Quadrupoles	17	SQA	Exist
	34	SQA	New
Trims (H)	25	MR trim	Exist
Trims (V)	25	MR trim	Exist
Lambertson	1	AO	Exist

All dipole magnets required for the two TeV injection lines, the F0-F17 magnet string and the F17-SY magnet string are recycled from the Main Ring. The only new magnets required are the F17 style Lambertsons and C-magnets required at the FMI extraction and Tevatron injection straight sections.

All quadrupoles used in the beamlines, except the 8 GeV line, are recycled 3Q84s or 3Q52s from the Main Ring.

Power Supply Requirements

The power supply requirements for all beamlines are summarized in Table 3-2. The power supplies will be located in the existing Booster Gallery, new North Hatch building, new MI-10, new extension to Main Ring F0, existing Main Ring F1 through F4 and the existing A0 Transfer Hall. All major dipole and quadrupole supplies for the 120 GeV and 150 GeV beamlines will be ramped to minimize the average power consumed. The 8 GeV line will run dc. Approximately 30% of the major dipole and quadrupole supplies will be reused from the present transfer lines. The kicker supplies will be located in the buildings at MI-10,-40,-52,-62, F0 (for E48), and F17.

3.6. The Abort Line

The details of the abort system are discussed in Section 2.10. For completeness, a discussion of the downstream magnetic elements is included here. Following the Lambertson and C-magnets which deflect the aborted beam 24 mrad downwards, the aborted beam is leveled off and deflected outwards by two B2 dipole magnets rolled at a 40° angle. In addition, three 3Q52 quadrupole magnets are placed in the abort line to maintain a suitable beam size for transport to the abort dump. The optics of this line has been designed so that all of these elements are powered in series with the FMI quadrupole bus, eliminating the need for one power supply. Some trim magnets and power supplies will be required for fine adjustment of the beam position at the dump. Sufficient free space exists in the downstream portion of the abort line for other magnetic elements which could be used to deflect the beam around the beam dump to future experimental areas. Figure 3-8 shows the layout of the magnets in the abort line.

Table 3-2 Beamline Power Supply Requirements

		Number of Circuits	Peak Load Current (KA)	Load RMS Power (KW)	Required PS Rating V/I/PWR
8 Gev					
Dipole	B1	1	0.895	47.9	60/1.0KA/65KW
	B2	1	1.293	90.8	80/1.5KA/120KW
	B3	1	0.679	25.7	45/800/36KW
	B4	1	0.499	109.8	250/600/150KW
	B5	1	0.930	25.0	30/1.2KA/36KW
Quad	Q1	1	0.147	33.5	275/175/48KW
	Q2	1	0.200	6.2	36/250/9KW
	Q3	1	0.255	13.6	60/300/18KW
	Q4	1	0.332	12.3	45/400/18KW
Trims	Bend	51	0.006	0.4	60/6/360
	Quad	17	0.025	0.3	10/25/250
150 Gev Proton/150 Gev P-Bar					
Dipole	B1	1	3.80	102.8	110/2.5KA/275KW
	B2	1	3.24	127.3	160/2.2KA/350KW
	B3	1	4.90	838.9	1,265/3.3KA/4.2MegW
	B4	1	1.48	18.1	55/1.0KA/55KW
	B5	1	3.45	35.5	45/2.3KA/105KW
	B6	1	3.60	64.1	80/2.4KA/192KW
Quad	Q1	1	4.00	88.0	85/2.7KA/230KW
	Q2	1	4.00	84.4	80/2.7KA/216KW
	Q3	1	4.00	233.0	230/2.7KA/621KW
	Q4	1	4.00	62.2	65/2.7KA/175KW
	Q5	1	4.00	48.9	50/2.7KA/135KW
	Q6	1	4.00	65.5	65/2.7KA/175KW
	Q7	1	4.00	64.0	65/2.7KA/175KW
	Q8	1	4.00	44.8	45/2.7KA/122KW
Trims	Proton	12	0.1	5.0	50/100/5KW
	P-Bar	12	0.1	5.0	50/100/5KW
F0-to-F17					
Dipole	B1	1	1.36	284.4	1,200/1.1KA/1.3MegW
	B2	1	2.84	303.0	480/2.4KA/1.2MegW
Quad	Q1	1	1.77	16.8	25/1.5KA/38KW
	Q2	1	2.63	37.2	40/2.2KA/88KW
	Q3	1	1.30	11.7	25/1.1KA/28KW
	Q4	1	1.29	34.6	75/1.1KA/83KW
Trims		2	0.1	5.0	50/100/5KW
F18-to-A0+					
Dipole	B1	1	1.36	783.6	3,000/1.1KA/3.3MW
	B2	1	0.65	5.6	35/600/21KW
Quad	Q1	1	1.36	174.6	350/1.1KA/385KW
	Q2	1	4.00	64.9	45/3.3KA/150KW
	Q3	1	4.00	92.3	65/3.3KA/215KW
	Q4	1	4.00	92.3	65/3.3KA/215KW
	Q5	1	4.00	92.3	65/3.3KA/215KW

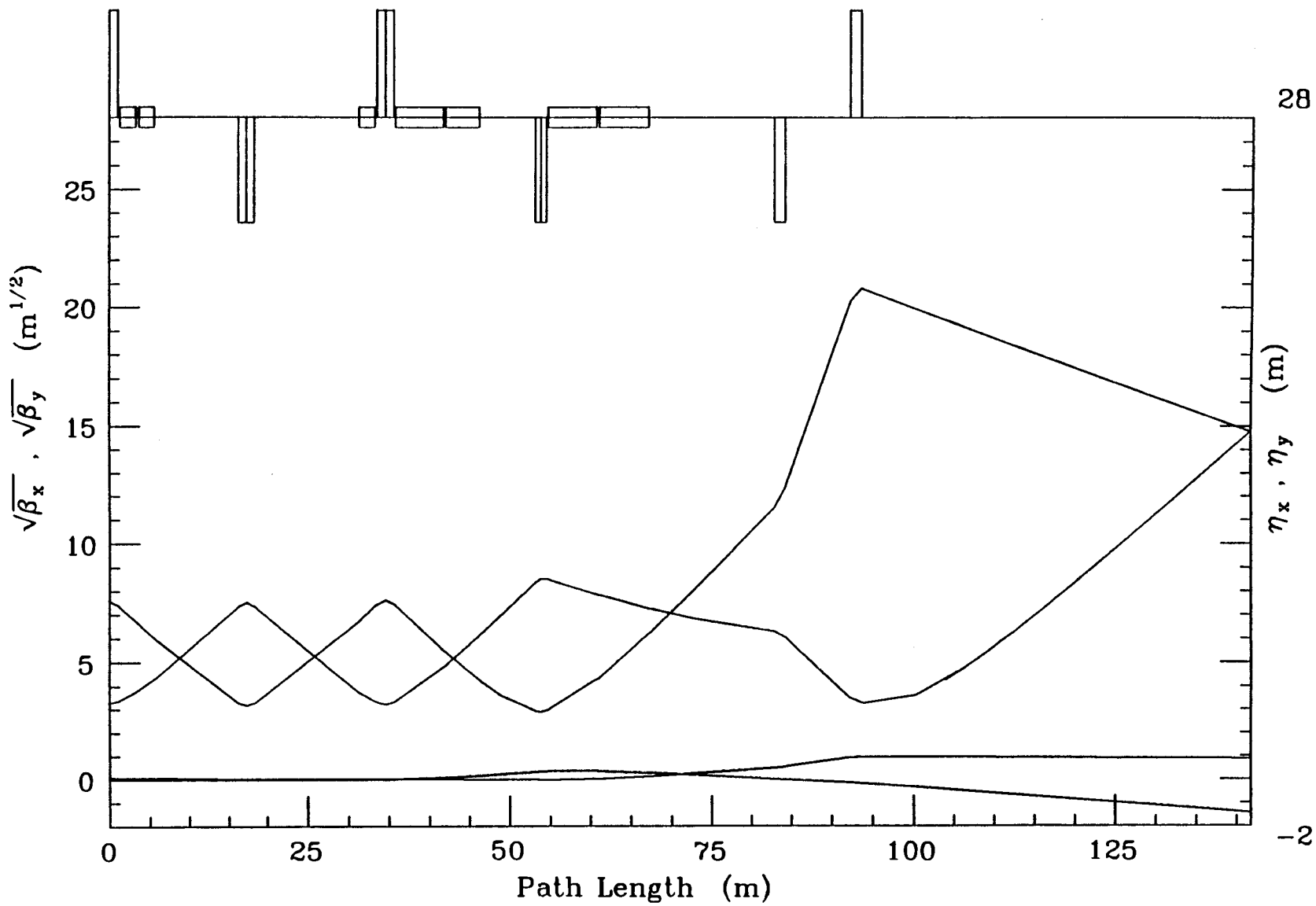


Figure 3-8. Layout and Lattice Functions for the Abort Line

4. CIVIL CONSTRUCTION

4.1 Overview

The civil construction for the FMI includes all below-grade beamline enclosures, shielding, above-grade buildings, roads, parking, cooling ponds, utilities, and services to accommodate the equipment for and operation of the FMI. The civil construction also includes the removal and replacement of a portion of the existing Tevatron ring enclosure to accommodate the new proton and antiproton injection beamline from the FMI into the Tevatron.

The below-grade enclosures include the FMI ring enclosure and the various beam transport enclosures which provide for the following beam transport lines:

1. 8 GeV protons from the Booster to the FMI.

2. 150 GeV protons from the FMI to the Tevatron.

3. 150 GeV antiprotons from the FMI to the Tevatron.

4. 120 GeV protons from the FMI to the Antiproton Source.

5. 8 GeV antiprotons from the Antiproton Source to the FMI.

6. 120 GeV protons from the FMI directly to the beam extraction lines for the fixed target areas.

New construction is similar to previously utilized and proven construction methods at Fermilab. The architectural style of the new buildings reflects, and is harmonious with, existing adjacent buildings. Existing topography, watersheds, vegetation, natural habitat and site boundaries have been carefully observed in the layout of the new construction. All these aspects are thoroughly addressed in the EA for the FMI.

Safety provisions for radiation, fire protection and conventional safety are included in this conceptual design and detailed in the PSAR for the FMI. Energy-efficient construction techniques will be incorporated into all new structures. Quality assurance provisions will be part of all project phases including conceptual, preliminary, and final design, construction, and construction management.

4.2 FMI Ring Enclosure

The FMI ring enclosure is an oval-shaped, below-grade enclosure, approximately 10,900' in length, with a 10'-0" wide by 8'-0" high typical cross-section. At utility alcoves opposite the five typical service buildings and the two kicker service buildings, the enclosure height is increased to 9'-0" and the widths are increased to accommodate utility penetrations, sump pumps, electrical panels, piping expansion loops and services crossing the enclosure width. Four additional utility alcoves will be provided midway between service buildings MI-10 through MI-50. Alcove lengths are nominally 16' but the total length of cast-in- place (CIP) concrete varies to match precast placing requirements. The enclosure plan and sections are shown on Drawing Nos. CDR- 11 through CDR-17. The floor of the typical enclosure is level at elevation 713'-6" or between 18' to 33' below existing grade. The FMI technical components for the circulating beam will be centered at elevation 715'-9" (more precisely at 715.724') and positioned nominally 2'-3" from the inside face of the outer enclosure wall.

Several segments of the FMI enclosure vary from the typical configuration to accommodate injection and extraction functions of the accelerator. The width at the 8 GeV injection area, shown on Drawing No. CDR-23 varies from 15' to 24'. At the proton abort region, the enclosure width varies from 15' to 22' while the base slab is stepped with the outer portion at elevation 712'-0" as illustrated on Drawing No. CDR-13. The MI-60 region will be approximately 460' long with a cross-section 15'-0" wide by 9'-0" high while the transition regions for the proton and antiproton injection to either side of station MI-60 are approximately 200' long with a width variation between 10'-0" and 26'-0" and a height varying in steps from 8'-0" to 14'-0". Drawing No. CDR-12 shows the plan of these areas and includes references to several drawings for appropriate sections.

Earth berms over the FMI typically provide the required 24'-6" earth equivalent shielding for unlimited occupancy resulting in a normal top of berm elevation of 746'-0". The extraction regions are shielded with 25'-0" of earth equivalent and the area adjacent to typical service buildings and between MI-60 and the F0 service buildings will be shielded at 26'-0" because of the future inaccessibility of these areas. Shielding is augmented by the use of steel plate where physical limitations preclude the ''all earth'' berms such as culvert crossings over the enclosure (see Section through Indian Creek Outfall - Drawing No. CDR-8) or at wave guide penetrations (see Stage 4, Section A on Drawing No. CDR-31). Where the natural terrain is higher in the western quadrant, existing grades will be modified to preserve the visual definition of the below-grade FMI ring enclosure.

The FMI ring enclosure is constructed on a reinforced concrete CIP base slab over a 3" thick lean concrete mud slab on undisturbed glacial till. Both

CIP and precast reinforced concrete wall and roof construction will be used but the majority of the typical cross-section segments (approximately 9,500') will be precast concrete inverted U-shaped wall/roof elements, which are welded to the CIP base slab. This is a proven construction procedure at Fermilab with nearly 26,000' of this type of precast enclosure placed during the past two decades. Drawing No. CDR-17 illustrates the typical precast element details and placing plan while the typical precast sections are shown on Drawing No. CDR-16. Segments of the enclosure requiring varying widths or special configuration, such as the injection or extraction regions and the alcoves will be constructed of CIP walls and roof as illustrated on Drawing Nos. CDR-13 and 28. Dampproofing, underdrains along the base slab and granular backfill at enclosure walls will be used to insure a dry enclosure.

Cable trays, power bus, LCW piping, lighting, convenience power and other services are ceiling- or wall-mounted. Numerous penetrations located at the alcoves or the atypical enclosure segments connect to the above-ground service buildings. All penetrations are designed to eliminate any line-of-sight configurations between the technical components and the service buildings above to maximize radiation protection.

Ventilation for the FMI enclosure, at the rate of two air changes per hour, is provided by above-ground pad-mounted air-handling units connected via buried ducts. Supply units with heating coils will be located at typical service buildings and the MI-60 service building with exhaust fans located between typical service buildings and at the kicker service buildings.

Equipment access to the FMI ring enclosure is provided at the MI-60 service building by an 8'-0" x 30'-0" open hatch and a freight elevator leading to a 10'-0" wide curved labyrinth illustrated on Drawing Nos. CDR-12 and 30. Personnel access to the FMI enclosure via stairs and labyrinths is provided at six locations around the ring, including the five typical service buildings and the MI-60 service building. The maximum distance of 2,100' to adjacent stairs occurs between service buildings MI-60 and MI-10 resulting in a maximum exit distance of 1,050'.

4.3 Beam Transport Enclosures

Although there are six functionally different beam transport lines (listed under Section 4.1 above), only three distinct new beam enclosures are required through the use of shared beam elements and shared enclosures. Drawing No. CDR-10 illustrates the various beamline directions and geometrics while Drawing Nos. CDR-11, 12 and 13 through 25 show the enclosure configurations in plan, cross-section and longitudinal section views.

The 8 GeV beam enclosure, connecting the existing Booster enclosure with the FMI ring enclosure, is a 2,100' long below-grade structure with a 11'-0" wide by 8'-0" high typical cross-section shown on Drawing No. CDR-23. The enclosure floor at the Booster connection will be at elevation 720'-6", or 2' below the Booster enclosure floor. Since the 8 GeV beamline slopes downward from elevation 726.552' at the Booster to elevation 715.724' at the FMI, the 8 GeV enclosure floor has a 7'-0" step to elevation 713'-6" approximately 200' from the Booster connection. This transition area is the location for a temporary vertical access hatch and a permanent personnel access stair from both levels to grade. This enclosure segment will be as wide as 16'-0" to accommodate the hatch and to facilitate the change in the 8 GeV beamline location relative to the enclosure wall. Components are centered 2'-10" from the west wall at the upper level (from the Booster) and 2'-10" from the east wall at the lower level (toward the Injector). The enclosure height also varies in this region to accommodate the sloping beamline components with a maximum height of 15'-0" where a ceiling mounted monorail with two 10-ton hoists provides equipment access to the upper level. Drawing No. CDR-19 illustrates the plan and longitudinal section at this transition segment. The 7'-0" wide by 24'-0" long hatch provides initial equipment access to the 8 GeV enclosure between the Booster and the crossing point of the antiproton enclosure for the AP2 and AP3 beamlines. The permanent equipment access at the North Hatch building must await the accelerator shutdown period before a permanent 8 GeV connecting segment can be constructed below the antiproton AP2 and AP3 enclosure (see Drawing Nos. CDR-21 and 24 for details of this crossing). Hence, once the technical components for the north portion of the 8 GeV enclosure have been installed via the temporary access hatch, it will be plugged with precast concrete shielding blocks, capped with a water-tight cover and topped with earth to provide the required shielding.

The 8 GeV enclosure will be constructed in the identical method described for the FMI ring enclosure with approximately 260' of the concrete walls and roof CIP while the remaining 1,840' will be comprised of precast inverted U-shaped elements. In addition to the aforementioned transition segment, CIP concrete will be required for the enclosure opposite the North Hatch building where a 10' wide equipment access labyrinth and utility penetrations intersect the enclosure (refer to Drawing No. CDR-22). Earth berms over the 8 GeV enclosure will typically provide 24'-6" of earth equivalent shielding required for unlimited occupancy.

The proposed 8 GeV enclosure connection from the Booster traverses an area with several active underground utilities, two roads, a parking lot and the nearby southwest Booster office building. Because the 8 GeV enclosure at this location is at a relatively shallow depth, the shielding equivalent of 24'-6" of earth will require a significant quantity of steel shielding to maintain the roads and minimize interference with existing

facilities. In addition, sheet piling, steel piles and timber lagging and retaining walls will be required to protect existing utilities and structures. While the methods of achieving the most cost-effective shielding will continue to be studied through Title I, the concept illustrated on Drawing Nos. CDR-18 and 25 demonstrates one feasible construction scenario. Work in this area will include a new personnel access stair connecting with the existing Booster enclosure downstream of the beam dump to provide a second exit from the upper level of the 8 GeV enclosure.

There will be a total of four personnel exits from the 8 GeV enclosure, including two on each level with the maximum distance of 1270' occurring between the North Hatch building and the vertical transition area resulting in an exit distance of 635'. As noted earlier, the primary equipment access will be via a 7'-8" x 30'-2" covered hatch at the North Hatch building connected to a 10' wide curved labyrinth.

At the time this CDR was issued, the technical components of the 8 GeV beamline had been revised to incorporate smaller existing Main Ring dipole magnets in lieu SDB dipoles. This change has not yet been reflected on the civil drawings. It is anticipated that the 8 GeV enclosure width can be reduced to 10' over much of its length, with larger radius enclosure bends requiring a slightly longer enclosure. These changes along with a reduced power requirement will be included in the forthcoming Title I.

The other two beam transport enclosures are the nearly symmetrical structures connecting the FMI and Tevatron enclosures. Identified by their major functions as the 150 GeV proton injection (P-150 GeV) and 150 GeV antiproton injection (A-150 GeV) enclosures, the plan is shown on Drawing No. CDR-12 with longitudinal sections on Drawing Nos. CDR-14 and 15 and the transverse section on Drawing No. CDR-16. In addition to the 150 GeV proton injection beamline, the southeastern enclosure also houses the 120 GeV proton beam from the FMI to the antiproton production target and the 120 GeV extracted proton test beam to the fixed target areas. These beams travel to the Tevatron enclosure at F0 where both beams are injected into a beamline arc composed of the former Main Ring accelerator components as far as either F-17 in the case of the antiproton production, or the the A0 Transfer Hall and the start of the Switchyard for fixed target beams in the case of the test beam. The 8 GeV antiprotons are transported to the FMI following the 120 GeV antiproton production line in reverse from F-17 to F0 and back to the FMI. While the injector beamlines are approximately 900' in length, a significant portion of their components are housed in widened portions of the FMI enclosure and the F0 sector of the Tevatron enclosure. The connecting 150 GeV segments are each 270' long enclosures with a width of 10'-0" and a floor elevation of 719'-6". The A-150 GeV enclosure has a height of 8'-0" except for a 28' long hoist area where 14'-0" will be provided. This area will include two parallel ceiling-mounted monorails each with a 15-ton chain hoist

to permit moving equipment from the FMI enclosure floor elevation of 713- 6" to the 719'-6" floor elevation of both 150 GeV enclosures and the lower level of the FO enclosure. The P-150 GeV enclosure will have a 10'-6" ceiling height to accommodate both the FMI and 120 GeV components. Both enclosures will be provided with a stair between the 719'-6" floor level and the FMI enclosure floor, and a personnel access stair and labyrinth to grade will be located near the FMI enclosure end of both enclosures. This arrangement results in a 766' distance between stairs to grade or a maximum exit distance of 383'. The 150 GeV enclosures will also be provided with an air barrier and door on either side of the FO Tevatron area to isolate the FMI underground enclosures from a potential ODH condition within the existing Tevatron enclosure. Except for the stair locations and the hoist area, the 150 GeV enclosures will be composed of precast concrete elements with all construction features similar to the FMI ring enclosure.

At the time this CDR was issued, considerable refinements had been made in the technical design for the 120 GeV and 150 GeV beamlines. The impact of these improvements on the civil design are currently under study and will be reflected in the Title I Design Report. It is anticipated that the height of the 150 GeV enclosures may be reduced, and the floor elevation will be lowered perhaps to the same 713'-6" elevation of the FMI enclosure with an accompanying simplification for equipment access to this portion of the enclosure.

4.4 FMI Service Buildings

Nine above grade service buildings in four size configurations house equipment, services and utilities for the FMI and the beam transport lines. The locations of the nine service buildings are shown on the site plan Drawing No. CDR-5 and the site criteria plan Drawing No. CDR-6.

Typical service buildings MI-10, MI-20, MI-30, MI-40 and MI-50 are identical in every respect except floor elevation. Drawing No. CDR-26 shows the floor plan and Drawing No. CDR-28 includes two sections through the typical service building. These buildings are located outside the FMI shielding berm approximately 1,800' apart. Since the buildings contain the magnet power supplies, the locations correspond to equal strings of magnets or approximately one-sixth of the dipoles in the beam enclosure below. The buildings also contain control racks, cable trays, pumps, a heat exchanger, deionizing bottles and controls for the LCW system, power distribution equipment and an air compressor. At two buildings, MI-10 and MI-40, power supplies and controls for kicker magnets (8 GeV injection and 150 GeV proton abort respectively) are also housed in a separate room with a depressed floor to retain oil spills. Each typical service building provides a direct personnel access via a CIP concrete service corridor over the berm to

a stair and labyrinth connecting to an alcove area of the injector enclosure below. The stair and labyrinth contain no utilities, cable trays or ventilation air for the enclosure. Supply or return air to the FMI enclosure alcove below is directed via a vertical duct to an outdoor air handling unit. A rated door at the base of the stairs and an outside door at the top of the berm provide an emergency exit from the FMI enclosure at each typical service building. The service corridor between the back of the service building and the interlocked doors at the head of the stairway provide three functions other than personnel access to the FMI enclosure. The 6'-0" width permits a 2'-6" wide utility aisle for dc bus in a protective enclosure, power, controls and LCW piping to extend from the building to penetrations which connect with the alcove below. The penetrations consist of steel tubes, PVC ducts, or piping which are vertically offset or shaped in a reverse curve to avoid any line-of-sight penetrations through the shielding berm. A door to the outside just before reaching the interlocked doors provides a second exit from the service building. And since the corridor is constructed of reinforced concrete and the aforementioned outside door will be protected against flying projectiles by a concrete retaining wall, the service corridor also serves as a tornado shelter.

The five typical service buildings are nominally 50'-0" square in plan with a clear interior height of 10'-0". The foundation consists of concrete spread footings extending to undisturbed bearing strata, concrete foundation walls, grade beams and floors, insulated metal siding erected on a structural steel frame and a built-up roofing membrane with insulation on a metal deck. Equipment access is provided by a 10'-0" wide by 8'-0" high roll-up door and two sets of double doors. A 1-ton monorail with chainfall will be provided in the kicker room at service buildings MI-10 and MI-40. Kicker room floor elevations are dropped 3" below the general service building floor level to retain any potential oil spills from the kicker supplies. A transformer yard will typically be located immediately outside the power supply room of each building. Outdoor equipment will include pad-mounted transformers for the dipole and quadrupole power supplies, conventional power transformers, vacuum circuit breakers and switchgear. Below grade concrete retaining walls filled with stone will be provided around the perimeter of all equipment containing oil coolants to serve as a spill basin. Because the proximity of the transformers to the power supplies significantly reduces power costs, the distance will be minimized and the service building will be protected by an 8" concrete block fire-rated wall adjacent to the transformer yard. All interior partitions will be concrete masonry units with hollow metal doors and frames. The electrical and mechanical systems for these buildings are described in detail in Sections 4.8, 4.9 and 4.10 below.

Service buildings will typically be located 25'-6" from the FMI beam centerline at a floor elevation slightly above the surrounding existing grade.

This siting arrangement provides a minimum of 26' of equivalent earth shielding between the service building and the FMI enclosure. Where possible, Indian Road will be located far enough from the service buildings to permit easy access for turning trucks. A hardstand area for vehicular parking will be provided on the side of the service building opposite the transformer yard.

Two kicker service buildings, MI-52 and MI-62, are located to either side of the MI-60 service building. These smaller buildings house power supplies and controls required for the kicker magnets in the 150 GeV FMI enclosures below grade. The building plan and section are shown on Drawing No. CDR-29. These service buildings are nominally 25' wide by 44' long with a 10'-3" inside clear height. No personnel access to the FMI enclosure is provided at the kicker service buildings and, hence, there is no service corridor tornado shelter. All other features of the typical service building construction are incorporated in these buildings.

The North Hatch building is sited along the 8 GeV beamline near the intersection of Kautz and Indian Roads. A plan of the building is shown on Drawing No. CDR-33 with typical sections shown on Drawing CDR-34. The North Hatch building is composed of a nominally 50' square low bay area with a 10'-0" clear height plus a 40' wide by 75' long high bay area with 28' clear height. Functionally, the low bay area mimics the typical service building except the kicker room has been replaced with a toilet area. The stair and labyrinth access to the 8 GeV enclosure is also of a different configuration but serves the same functions of an exit from the below grade enclosure to a direct outside egress, tornado shelter and second exit from the service building. Power supplies, controls, LCW cooling equipment, and penetrations service the dipole and quardrupole magnets of the 8 GeV beam line.

The high bay of the North Hatch building primarily provides equipment access to the same 8 GeV beam enclosure. A 7'-8" x 30'-2" hatch is located at one end of the high bay connecting directly with a semi-circular 10' wide labyrinth at elevation 713'-6". The hatch will be covered with 1'-6" thick precast concrete blocks as additional shielding whenever the 8 GeV beamline is operational. A 12' wide by 13' high roll-up door provides truck access to the high bay which is serviced by a 30-ton bridge crane with an 18' hook height. The high bay will also serve as a magnet storage and staging area for the 8 GeV beam line. Other features, including utility penetrations to an enclosure alcove, earth shielding parameters, transformer yard, hardstand and all construction features, are similar to those described for the typical service building.

The largest of the new service buildings will be located parallel to and southwest of the MI-60 segment of the FMI enclosure directly across the berm

from the existing FO service building. The MI-60 service building, illustrated on Drawing No. CDR-30, houses a number of functions, including two power supply areas at opposite ends of the building for dipole and quadrupole magnets, all power requirements and controls for the FMI rf cavities, a pump room and deionizing facility for LCW, technician space, rf development laboratory, magnet test area, the FMI control room, and toilet facilities all located in a 20,000 sq.ft. low bay area. An adjacent 5,000 sq.ft. high bay features an open 8'-0" by 30'-0" long hatch connecting directly with a curving 10' wide labyrinth at elevation 713'-6" which is the equipment access for the entire FMI ring enclosure and the 150 GeV FMI enclosures. A 12' wide by 13' high roll-up door provides truck access to the high bay which is serviced by a 25-ton bridge crane with an 18' hook height. A 5,000 pound capacity freight elevator and a stairway located immediately adjacent to the high bay area provide additional access to the FMI enclosure below. The stair and adjoining labyrinth provide a rated exit for the MI-60 enclosure and the lower elevator lobby and hatch area serve as a tornado shelter. The high bay space will also serve as a staging and storage area for the FMI magnets and other beam line components.

The MI-60 service building will be 450' long with a low bay width of either 25' or 50' while the high bay measures 50' by 100'. As indicated on the building sections shown on Drawing No. CDR-32, the floor elevation of the MI-60 service building is set at elevation 742'-6" to match the existing FO service building floor and the clear interior heights are 12' for the low bay and approximately 28' for the high bay. The majority of the low bay area will be provided with a continuous floor trench located along the northeast wall which will provide access to the numerous utility penetrations leading to the MI-60 enclosure. The cross-section also illustrates the 8'-0" wide by 8'-0" high passageway connecting the MI-60 service building and the existing FO service building for personnel and control cabling access. The MI-60 service building will be positioned far enough from the FMI enclosure to provide 26' of equivalent earth shielding to the lower outer corner of the aforementioned cable trench. Steel shielding will be added below the connecting passageway to achieve the same level of radiation protection.

Transformer yards will be located at either end of the MI-60 service building as well as directly southwest of the LCW pump room. Anode power transformers will be housed in special enclosures connecting to the rf gallery and because the entire service building is air conditioned, two 125-ton pad-mounted chillers will also be located southwest of the building. In addition to the high bay area, equipment access via roll-up doors will be provided at each beamline power supply room at the ends of the building. Construction features will be identical with those outlined for the typical service buildings, except that the wall adjacent to the berm will be CIP concrete.

4.5 F0 Beam Enclosure and F0 Service Building Addition.

The F0 beam enclosure, as shown on Drawing No. CDR-12, encompasses the long straight section of the existing Tevatron enclosure. This region will house components from the accelerator(s) to be relocated from the existing Main Ring, as well as from several beam transport lines. Functionally, these are elements of the 150 GeV proton injection line, the 150 GeV antiproton injection line, the 120 GeV antiproton production line, the 8 GeV antiproton accumulator to FMI line, and the 120 GeV extracted test beam line. As noted above, some of these lines share common elements or share common enclosures. But the existing F0 long straight sections has insufficient space for the new transport beams to be included in addition to space required for the existing Tevatron rf cavities and beamline components. Hence, except for the equipment access labyrinth at the south end, the 375' long F0 long straight section must be demolished and rebuilt. Since the western portion of the existing rf service building is located directly above the F0 enclosure it, too, must be demolished and replaced with an addition along the opposite side of the remaining service building. Drawing No. CDR-31 shows cross-sections through the MI-60/F0 area in four stages of construction illustrating the construction sequence proposed. One of the basic design premises requires that the entire FMI enclosure can be constructed while the Tevatron remains operational. Hence, the FMI lattice has been designed to provide sufficient lateral distance between the F0 enclosure of the operating Tevatron and the excavation required for the MI-60 enclosure to insure at least 21' of equivalent earth shielding. Stage 1 on Drawing No. CDR-31 shows this initial condition will require two lines of sheet piling with two levels of walers and horizontal braces to maintain the existing F0 enclosure, the F0 service building above and provide the necessary shielding. Since the MI-60 service building is required to provide equipment access to the FMI enclosure and will also provide space for early power supply testing, this service building will be constructed during this initial phase. The 20' wide addition to the northeast side of the existing F0 service building can also be completed during this phase. The existing northeast wall will remain in place during the construction of the addition to preserve a working environment in the existing building. See Stage 2 on Drawing No. CDR-31.

Once the shutdown of the Tevatron beam operation commences, equipment will be relocated from the southwest portion of the existing F0 service building to the new addition and demolition will begin. After the southwest portion of the above grade F0 service building is removed along with helium transfer lines and the upper portion of utility penetrations, a third line of sheet piling will be driven between the remaining section of the F0 service building and the northeast side of the underground Tevatron enclosure at F0. This condition is depicted as Stage 3 on Drawing No. CDR-31. The Tevatron rf cavities, bus, cable trays, control cabling and other beam

line equipment will have been moved out of the F0 enclosure prior to pile driving. Excavation and demolition will commence after the third line of piling is adequately braced back to the existing sheet piling left in place from the MI-60 enclosure construction. The F0 enclosure to be removed consists of approximately 200' of CIP concrete walls and roof with the remaining 175' composed of precast concrete hoop elements. The CIP area will be sawcut into 6' long segments, sawcut along the base of the wall and core-drilled to provide lifting points. Then these concrete pieces along with the precast elements will be removed and hauled to an on-site storage location for future use. The CIP concrete slab will be demolished and the debris deposited in the excavation.

The reconstructed Tevatron rf enclosure, shown in Section D on Drawing No. CDR-16, will be a CIP concrete structure except for precast roof beams which will be used as a composite roof element with the CIP concrete to speed construction and avoid interior shoring. The floor will be constructed at two elevations - 719'-6" to match the connecting 150 GeV proton and antiproton enclosures and 722'-6" to match the existing Tevatron enclosure. The enclosure width will vary in steps from 20'-0" to 24'-0" to meet the requirements of the diverging beam lines as indicated on Drawing No. CDR-12. The ceiling elevation of 730'-6" provides a minimum clear height of 8'-0" on the F0 side which matches the existing Tevatron enclosure height. The 11'-6" height on the FMI side of the enclosure is one foot higher than the 150 GeV injector enclosures. The reconstructed F0 enclosure will connect with the existing curved access labyrinth leading to the stair and freight elevator in the present F0 service building. As noted earlier, this enclosure will also connect with the two 150 GeV injection enclosures but a physical barrier with an air-tight door in both injection enclosures will isolate the ODH possibility of the Tevatron enclosure from the FMI enclosure. Construction will require utility penetrations including right-angle type conduits for the Tevatron waveguide penetrations. The latter group will require a vertical manhole at each waveguide for installation access which will later be plugged by steel and concrete and covered by a hatch. The shielding requirement of 26' of equivalent earth must be imposed upon the existing juxtaposition of the Tevatron beamline and the remaining portion of the F0 service building. As shown in Stage 4 on Drawing No. CDR-31, it will be necessary to abandon the existing utility trench and a portion of the floor area in order to construct an earth embankment inside the existing building. L-shaped precast concrete retaining walls will be used to minimize the earth encroachment and the earth will be capped with a concrete slab. Fortuitously, the existing southwest wall is constructed of CIP concrete which will permit earth backfill placement on both sides. For those limited areas of the F0 service building where function or space requirements preclude the interior earth shield, exterior steel shielding will be added as the excavation is backfilled. The limits of the interior earth fill are shown on the building

plan on Drawing No. CDR-30 and the areas of steel shielding are shown on Drawing No. CDR-12. The middle line of sheet piling and all the walers and braces will be salvaged from the earth retention system. The outer two lines of sheet piling will remain in place primarily because the numerous utility penetrations effectively "trap" the piling. The final earth backfill will provide 26' of shielding above the F0 and MI-60 enclosures. The helium transfer lines will be reinstalled along the top of the completed berm. Underdrains, dampproofing and granular backfill at the walls are used to insure a dry enclosure. Cable trays, power bus, conventional power, LCW piping and other utilities will be installed as shown on Section D of Drawing No. CDR-16.

Recent redesign of the 150 GeV beamlines now included in the technical chapters of this CDR have introduced changes that will alter the reconstructed Tevatron enclosure at F0 described in this text and accompanying drawings. These changes will be reflected in the Title I design of the reconstructed F0 enclosure.

The F0 service building addition will be 20'-0" wide by approximately 215' long encompassing a floor area of 4,345 sq.ft. The addition will house equipment displaced by the shielding requirement such as Tevatron rf power supplies and controls, beamline power supplies and a control room. This construction must be preceded by the relocation of approximately 650' of Main Ring Road and some utilities to allow space for the addition. A separate 24' wide by 45' long compressor room extension will also be added to the southeast end of the F0 service building to house helium compressors and related Tevatron cryogenic equipment relocated from the E0 service building. Both additions will have a clear interior height of 12' and construction will be identical with the typical service buildings. Once the F0 service building addition is complete, the existing former exterior wall will be removed to result in a 45' wide general space. Exterior transformers, anode power transformers and chillers will be provided to augment existing equipment.

Technical requirements have determined that a separate kicker service building will be required for injection of the 120/150 GeV proton beams to be located northwest of the F0 service building. The current civil CDR scope assumed this function could be accommodated by the MI-60 service building but proximity requirements indicate an F17 kicker building measuring 16'x32' located 120' from F0 will be more cost effective. This building addition with a compensating change in the MI-60 service building will be incorporated in the Title I Design Report. The antiproton (E48) kicker will be located in the F0 building.

4.6 Assembly Building No. 5

The Assembly Building No. 5 (AB-5) is currently proposed to be used for component fabrication and final assembly for many of the FMI magnets. The addition of this building in the Fermilab industrial area would allow magnet production to be completed without impacting other Fermilab on-going magnet programs.

AB-5 will be located north of the present industrial area rear parking lot and immediately west of the present Industrial Building No. 3. Refer to Drawing No. CDR-35. Siting the new building in this location will allow use of the existing parking areas and will provide convenient access to the other facilities and personnel in the industrial area. Utilities and services are available nearby for extension to the new building. Minor reworking of a drainage ditch and extension of a storm sewer are required. Based on soil borings and previous construction at the Industrial Center Building, shallow concrete caissons are an economic choice for the building foundation.

The exterior of AB-5 will match the appearance of the four sister Industrial Buildings No. 1 through No. 4. The steel frame building will have a high bay 60' wide by 192' long with a roof height of 30'. A 30' wide by 192' long enclosed mezzanine for tech space will be located along the northwest side of the building. The mezzanine floor will be 16' above the ground floor. Enclosed stairwells are located at each end of the building and the mezzanine will also be serviced by a hydraulic personnel elevator. The ground floor area below the mezzanine will include toilet rooms, mechanical space and a shop area. The high bay will be serviced by a 50-ton bridge crane with an 18' hook height. A 5'-1" high concrete kicker wall at grade is topped by a 1'-6" high strip of horizontal windows. Insulated vertical metal siding completes the wall system. Vertical windows will be provided on the northwest wall above the mezzanine floor. Equipment access will be provided on three sides of the building via roll-up doors with opening sizes up to 16' wide by 16' high with eight personnel doors spaced around the building perimeter.

All areas in AB-5 will be air conditioned. Lighting levels and power outlet distribution will be similar to the other industrial area buildings. A 1,500 kVA substation will be installed near the west end of the building and will connect to a 2,000 amp switchboard for the various power needs within the new building.

As this CDR is being issued, it appears very likely that significant numbers of the FMI magnet requirements will be procured from outside commercial sources thereby eliminating the need for AB-5. The Title I document will not include this proposed facility.

4.7 Foundation Systems, Earth Retention and Active Soil Control

All base slabs for the FMI enclosures will be founded on glacial till with high bearing capacities in excess of 3,000 psf. Soil boring locations, elevations of the glacial till and unconfined compressive strengths are shown on Drawing No. CDR-3. Additional borings are currently being taken to augment earlier information especially where earth retention systems will be required. Future borings will also be taken at each tower location along the 345 kV transmission line after the final route is determined.

Foundations for the service buildings will generally consist of spread footings located below frost level with perimeter foundation walls. Where footings are located within the limits of the enclosure excavation, the footing elevation will be dropped to bear an undisturbed material and the load carried by concrete piers and grade beams. The service corridors passing over the berm between the service buildings and the stair to the enclosure will be supported by three concrete piers bearing on the alcove structure below. Because the corridors are constructed of CIP concrete, there will be adequate structural stiffness to bridge between the deep and shallow foundations. The pier supports at the service corridor also eliminate differential settlements between the structure and utility penetrations.

Earth retention systems will be used during the various construction phases in order to retain foundations of existing beam enclosure structures. In addition, the retention systems will contain and confine much of the active soil adjacent to these existing beam enclosures. With these methods, the entire FMI ring enclosure and much of the beam transport enclosures may be built during normal accelerator operations.

Sheet piling, driven beside the existing Tevatron F0 enclosure and F0 service building will allow construction of the FMI ring enclosure and MI-60 service building during accelerator operations. This sheet piling will be driven parallel to and 21' beyond the outer radius of the the Tevatron enclosure to an approximate depth of 42' for a length of 840'. Refer to Drawing Nos. CDR-12, CDR-30 and CDR-31.

A second row of parallel sheet piling approximately 650' long will be driven along the southwest side of the proposed FMI MI-60 enclosure to be supported by horizontal bracing between the two piling rows and to permit excavation and construction work. After the MI-60 enclosure is completed and partially backfilled, the horizontal bracing will be removed and re-used. The sheet piling will remain in place.

After the Tevatron accelerator shutdown commences and the demolition of a portion of the existing F0 service building is complete, a third line of sheet piling will be driven between the remaining F0 service building and

the Tevatron F0 enclosure for a length of approximately 550'. Horizontal bracing will be modified and reinstalled between the first and third piling rows. After excavation between the sheet piling, the Tevatron F0 enclosure will be demolished and rebuilt and the connecting portions of the 150 GeV injection enclosures will be completed.

Soils excavated from areas adjacent to existing Tevatron enclosures that exhibit low levels of activity will be carefully segregated, controlled and subsequently backfilled into areas adjacent to the reconstructed enclosures. Soil storage pits next to required excavations will be dug as a repository for all active soils removed during construction. The active soil bulk will be covered with an umbrella of clay soil for temporary protection and containment during the construction period. Surface water will be controlled and diverted away from these storage pits. Demolished concrete from the base slab of the Tevatron F0 enclosure will be left in the bottom of the excavation at documented locations and backfilled.

4.8 Master Substation, Primary and Secondary Power Distribution

Power is provided to the FMI via a new 345 kV overhead transmission line, a new 345 kV substation and 13.8 kV power feeders in ductbanks to various substations and secondary distribution for three FMI power systems. These systems as discussed in Section 2.14 above are: 1) Pulsed Power Supply Power System, 2) Conventional Power System and 3) Beamline Power System.

A new 345 kV switching station will be installed at the southeast corner of the Fermilab site along the Commonwealth Edison Co. transmission line corridor paralleling the EJ&E railroad tracks. Refer to Drawing No. CDR-1. Two manually-operated 1,600 amp, 345 kV switches will connect to Commonwealth Edison Co. transmission lines No. 11119 and No. 11120.

A new overhead transmission line, approximately 13,200' long will be installed along the southern boundary within the Fermilab site, at least 500' from Illinois Highway 56, Butterfield Road. The line will bend northward along Kautz Road and will terminate at the new Kautz Road Master Substation (KMS). Double arm steel poles at an average spacing of 750' will carry a single 345 kV circuit with static shield wires above.

The new KMS will be located east of Kautz Road approximately 900' from nearest arc of the FMI, 0.5 miles from the south site boundary and 1.6 miles from the existing Master Substation (MSS) at Road A-1 and Road B. The new substation area is well drained and lies east of wooded areas that abut the Tevatron ring between E-3 and E-4.

The new KMS will consist of an 188,000 sq. ft. rock base enclosed with a security fence with access gate to Kautz Road. Within this area will be the 345 kV dead-end structures, aluminum tubular bus bars and insulators, motor operated 345 kV switches, SF-6 main circuit breaker, four transformers, and a walk-in structure for secondary switchgear equipment. Foundation pads and vaults, oil containment sumps, lightning protection and ground grids are also included.

Two new transformers and two existing transformers from the present MSS will be installed in the new KMS. Refer to Drawing No. CDR-42. The new transformers will be 40 MVA capacity (40/53/66.6 MVA-OA/FA/FOA), 345/13.8 kV, 3-phase, 60 Hz oil filled and will be used for the FMI pulsed power supply and beamline power systems. An existing 60 MVA transformer 82B, that will be retired from Main Ring pulsed power supply service, will be used for the FMI conventional power system. Another existing 40 MVA transformer 84A, currently an MSS on-line spare, will be moved and reinstalled in the new KMS.

The secondary sides of the four transformers will be connected by 3,000 amp, 13.8 kV non-segregated outdoor bus to 13.8 kV, SF-6 type main and feeder breakers with sufficient interrupting capacity for the available short circuit currents. These breakers, together with metering, relaying and communication equipment are all housed in an enclosed metal walk-in structure.

Underground concrete-encased ductbanks with precast concrete manholes will route the 13.8 kV feeders from the new KMS to the various FMI power systems. Refer to Drawing No. CDR-42. Other ductbanks will connect back to the Main Ring ductbank near E-2 and E-3. These connections and the use of six existing Main Ring feeders provide the future capability of supplying 40 MVA of back-up power to the MSS.

The Pulsed Power Supply System is fed from the new 40 MVA transformer in the KMS through three 13.8 kV feeders for FMI ring pulsed power and one 13.8 kV feeder for FMI beamline power. The FMI ring uses three loop feeders carried through an underground ductbank, the ends of which connect through switchgear at the KMS and near the MI-50 building area. At each service building, there is a disconnect switch to supply power to the power supplies. This routing is shown in Drawing No. CDR-41. A paralleling switch at MI-30 will enable uneven loading of each segment without overloading the feeders. This switch can also be used for feeder isolation for maintenance purposes. The power for the beamlines will require one feeder with (2) 1,500 kVA substations at MI-60, and one 1,500 kVA substation at the North Hatch building.

The Conventional Power System will be fed from the relocated transformer 82B and will consist of one 13.8 kV feeder around the FMI ring, with a 500 KVA transformer at each of the principal ring service buildings and a 750 KVA at

the North Hatch building. The conventional power will be used for building power, lights, pumps, heating and air conditioning. At each service building there will be a disconnect switch with a ductbank connection to the conventional power transformer. Conventional power will be connected to power distribution panelboards in each service building. Power for the water pumps, heating and ventilating equipment, control racks and service outlets will be provided by 480/277 volt, 3-phase branch circuits. Step-down transformers and panelboards provide 208/120 volt power for lighting and outlets. Separate panelboards for isolating beam equipment at 480/277 volt and 208/120 volt are provided. Refer to Drawing No. CDR-26.

4.9 Primary Cooling, Distribution and Mechanical Systems.

The primary heat rejection medium for the 18.5 MW water cooled load generated by the FMI is cooling pond water (PW). Drawing Nos. CDR-38 and CDR-39 show the eight new interconnected cooling ponds (A thru H) that roughly encircle Indian Road and provide 17.5 acres of cooling surface. The ponds total 11,750' in length, range from 30' to 90' in width and generally have a depth range of from 4'-6" to 7'-0". A transverse concrete dam near service building MI-30 provides for a change in water level between Ponds D and E. Generally, PW levels vary from elevation 739', matching the existing Main Ring ponds at the FO area, down to elevation 735'. Transfer piping between the FMI ponds and the existing Main Ring ponds allow for make-up and water level control.

As described in Section 2.13, the LCW system is a closed-circuit piping loop exchanging heat from the FMI rf area, beamline magnets and power supplies to the PW. Much of the equipment now in use in the present Main Ring service buildings will be relocated to the new FMI service buildings and perform in a similar capacity. New LCW piping will be installed in the FMI beamline enclosures. Primary deionized water will be supplied to the FMI LCW system along piping in the 8 GeV enclosure from existing polishing system at the Central Utility Plant. This plant will also be fitted with 3,000 gallons of LCW tanked storage for make-up use in the FMI similar to the existing Main Ring system. An additional 1,000 gallon FMI LCW system expansion tank will be provided at service building MI-30. LCW system continuous slip-stream polishing deionizer bottles will also be located at the North Hatch building, FO building and five typical service buildings. These deionizing bottles will be periodically taken to the Central Utility Plant for regeneration much the same as similar bottles presently on site.

Existing chilled water (CW) in the FO service building, which comes from the Central Utility Plant, will be retained, reused and extended into the new MI-60 service building. The new combined loads on the CW system are comparable to the present loads.

The underdrain system for all new beam enclosures is similar to the design used for the existing antiproton rings. Perforated drain piping surrounded by granular material and covered with geotextile fabric will be installed on both sides of the enclosure base slabs. Duplex pump sump pits connect to the underdrain piping and discharge into surface ditches, as shown on Drawing No. CDR-39.

Moderate ventilation rates with dehumidification will be used in the FMI enclosures. Drawing No. CDR-36 presents a general layout of this arrangement. Ventilation supply fans with filters and electric heat are located at each service building with exhaust fans at intermediate points between, all connected by underground ducts to alcove areas of the FMI enclosures. Two air changes per hour will be provided when needed during non-operating periods. Periodically spaced dehumidification units about the enclosures will control humidity.

The FMI service buildings are equipped with a variety of HVAC systems to accommodate the required occupancy, as outlined on Drawing Nos. CDR-36 and CDR-37. Local split-system air conditioning units with electric heat will provide temperature control in all kicker rooms and control rooms in the FMI North Hatch, kicker and typical service buildings. Electric unit heaters and filtered ventilative cooling supply fans with interlocked relief louvers will serve pump rooms, power supply rooms and magnet staging and storage areas in these same buildings. Temperature control at the FO/MI-60 service building will be provided by HVAC units with electric heat and fed from local central air-cooled chillers totaling about 375 tons capacity. All of the above buildings will be equipped with required ventilation provisions.

4.10 Fire Alarm, Detection and Suppression Systems

All FMI structures will be provided with fire protection systems as scoped on Drawing No. CDR-36. Automatic sprinkler systems will be supplied from a direct buried 12" diameter industrial cooling water (ICW) loop encircling the FMI and tied into the existing site ICW fire protection system in two places, just north of the FO area and just south of the existing antiproton ring. Hydrants provided at each kicker and service building will be of the draft type, fed from the FMI cooling water ponds. All areas will be provided with code-required signage and local alarms and will be connected to the existing site-wide FIRUS monitoring system for reporting alarms and trouble conditions. Beamline enclosures will have quick response sprinklers in stair alcoves and standpipes in exit enclosures, with combination fixed temperature/rate-of-rise heat detectors and manual pull stations. All above grade buildings will have ordinary hazard wet type sprinklers with manual pull stations and smoke detectors. An independent fire protection consultant has been engaged by Fermilab to review the safety requirements of the FMI project, including fire detection/suppression and exiting designs

with respect to recognized codes and standards. These findings have been incorporated into the PSAR currently under review by DOE.

4.11 Environmental Concerns and Actions

Detailed and specific definitions of the wetland areas, floodplain and storm water management, archaeological concerns and ecological resources have been identified by environmental consultants resulting in the preparation and submittal of a Floodplain/Wetland Assessment Report and an Environmental Assessment (EA). As a result of these efforts, the following approvals/permits have been obtained:

AGENCY	ACTION REQUESTED	ISSUED
Div. of Air Pollution Control Illinois Environmental Protection Agency Springfield, Illinois	Application for Permit to Construct Il. Adm. Code 201.142 NESHAP ID # 0438 07AA1	April 1, 1991
U.S. Environmental Protection Agency Region V (SAC-26) Chicago, Illinois	Application for Permit to construct 40 CFR Part 61.07 Radionuclides National Emission Standards for Hazardous Air Pollutions (NESHAP) REF: 5AT-26	May 9, 1991
Division of Water Pollution Control Illinois Environmental Protection Agency Springfield, Illinois	Clean Water Act Section 401, Water Quality Certification	June 4, 1991
Department of the Army Chicago District U.S. Corps of Engineers Chicago, Illinois	Clean Water Act Section 404, Nationwide 26 Permit Application No. 3499102	June 26, 1991
U.S. Dept. of Agriculture Soil Conservation Service Champaign, Illinois	Farmland Conversion Impact Rating	Sept. 18, 1991

In addition, other environmental agencies have been consulted resulting in the following accords:

AGENCY	CONSULATION REQUESTED	ISSUED
U.S. Fish & Wildlife Service Rock Island, Illinois	Consulation in Accordance with Fish & Wildlife Coordination Act 48 Stat. 401 16 U.S.C. 661 Endangered Species Act	April 30, 1991
Illinois Dept. of Conservation Springfield, Illinois	Consultation in Accordance with Fish & Wildlife Coordination Act	June 20, 1991
State Historical Preservation Officer Illinois Historic Preservation Agency Springfield, Illinois	106 Determination of No Effect 36 CFR 800	July 22, 1991

As this CDR is issued, only three environmental-related issues remain unresolved. The EA has been amended to reflect comments and is presently under final review by the DOE. A draft FONSI accompanies the EA and it is anticipated that publication in the Federal Register of the draft FONSI for a public comment period of 30 days is imminent. As explained in the EA, a great blue heron rookery exists inside the FMI ring. While the herons abandoned this rookery in 1991 to take residence near the center of the Main Ring, it is conceivable they may return while the FMI is under construction. It is recognized that limits must be imposed on construction proximity during the heron nesting season. However, the buffer zone radius, which is dependent upon noise levels, is not a well-defined value. Therefore, noise tolerance levels have been under study during 1991 at Fermilab and the results will be used to derive the construction activity limits. Finally, Fermilab is preparing and will submit an application for a NPDES Stormwater Permit pursuant to the publication of the revised regulations.

As a result of the Fermilab environmental efforts, the FMI design and construction will incorporate the following features:

a. Modifications of the original FMI plan have avoided wetland impact so that the current design will require permanent filling of only 5.70 acres. This area represents less than 6% of the wetlands located within the immediate environs of the FMI project.

b. Pursuant to COE standards, 8.6 acres of mitigation area, representing a 1.5 to 1.0 ratio of filled wetlands, will be constructed near Indian Creek within the limits of the FMI berm. The 8.6 acres will be divided into approximately 2.3 acres of sedge meadow with the remaining 6.3 acres wooded to mimic the existing W4 wetland habitat.

c. While the FMI project is located within the Indian Creek floodplain, the design will insure no increase in the high water elevation or total discharge flow for a 100 year storm at the Fermilab site boundry. A compensatory storage area of 29 acre-feet will be constructed within the floodplain to offset the FMI construction. Stormwater flows through the wetland areas will be designed to insure adequate supplies.

d. Three archaelogical areas have been identified in the vicinity of the FMI but none will be disturbed by construction activities. The Tadpole, Pioneer and Lorenz sites will be permanently fenced to preclude any interference.

e. Ecologically, the FMI proposed construction affects less than 4% of the undeveloped areas of the Fermilab site and hence will have no significant effect on Fermilab's biological communities or the Laboratory's status as a National Environmental Research Park. No federal- or state-protected species were identified within the FMI construction area. The proposed measures for avoiding impacts to the heron rookery have been sanctioned by the U.S. Fish and Wildlife Service.

5. COST ESTIMATE

The TEC for construction of the FMI, associated beamlines, and required modifications to existing facilities is $213,300,000 in then-year dollars. The cost estimate is summarized in Table 5-1. An additional $29,100,000 is required in direct R&D, pre-operating, capital equipment, conceptual design, and spares costs to support the project. The cost estimate methodology is based on a Work Breakdown Structure (WBS) which has been developed for this project over the last few years. Our recent experiences with the TeV I (Antiproton Source), Main Ring overpass, and Linac Upgrade construction projects form the basis for a large fraction of the cost estimate of this project.

5.1 Methodology

A WBS is set up in order to identify all required components of the FMI project and to insure that each component is adequately specified and incorporated into the estimate. The WBS through third level is shown implicitly in Table 5-1. The actual WBS used for the cost estimate extended through the seventh level.

All components are estimated at the lowest applicable level in 1991 dollars and then summed upwards. At the lowest level materials costs and labor (fabrication) hours are entered separately along with the basis for the estimate. Labor estimates are associated with a craft code specifying the type of labor to be used. When materials costs are based on previous purchases of identical components they are escalated to 1991 prices using standard DOE inflation factors. The translation of craft codes into hourly costs is based on current local labor rates and is given in Table 5-2. Through this approach a categorized estimate of the total manpower required for completion of the project is created at the same time as the cost estimate. The manpower estimate is given in Table 5-3.

The cost estimate is produced in 1991 dollars. The TEC in $1991 is $187,500,000. Escalation to then year dollars is accomplished through a convolution of the cost spending profile with DOE construction project escalation rates.

5.2 Technical Components

The technical components of the rings and beamlines include magnets, vacuum, rf, diagnostics, controls, and safety systems. Included in the estimate are materials, fabrication, and installation costs. The total cost estimate for these components is $79,900,000 (1991). Engineering design and inspection (ED&I) are included in the component cost. All components are similar to components already built and installed at other locations within the Fermilab complex. The only extraordinary items are the new dipole magnets

and the 9,000 amp power supply. A modest R&D effort is associated with these items.

5.3 Civil Construction

The civil construction cost estimate includes the FMI ring enclosure, beamline enclosures, service buildings, modifications to the Main Ring enclosure and service building at F0, and all associated utilities including primary power and water distribution. Also included are the requisite sitework and road development. Specifically provided for are new cooling ponds, environmental restoration of impacted wetlands, and the new 345 kV Kautz Road Substation.

The total civil construction is estimated at $70,200,000 (1991). Specifically included are funds targeted for environmental mitigation (accounted for in WBS 1.2.1). Costs are estimated on the basis of quantity take offs and include contractor overhead and profit. The ED&I component of the cost assumes the use of an outside architectural and engineering (A&E) firm for design work on all civil components removed from the interface between the FMI ring and existing facilities.

5.4 Engineering Design Inspection & Administration (EDIA)

ED&I is incorporated into component costs at the lowest applicable WBS level and summed upwards. Project management costs are explicitly estimated under WBS 1.3. Total estimated EDIA as a fraction of the total components cost is 16.2% (including 11.8% for ED&I, 3.3% for project management, and 0.7% for G&A). The G&A rate is the established incremental overhead on construction projects at the laboratory. EDIA is estimated at $21,800,000 (1991).

5.5 Contingency

Contingency is assigned to all technical components on the basis of the cost estimating procedure. Estimates based on previous actual purchases, on vendor quotes, or on catalog prices are assigned a 15% contingency. Estimates based on undocumented engineering estimates (approximately 19% of the total materials cost estimate for the project) are assigned a 20% contingency. An across-the-board 20% contingency is applied to all labor estimates. Special allowances have been provided for the possible impact of procuring dipole magnets from industry ($4,000,000) and for unanticipated refurbishing expenses associated with the reuse of existing quadrupole power supplies ($600,000). Civil construction contingencies are assigned at the third WBS level on the basis of previous experience with similar projects.

The total contingency assigned to the FMI project is $31,500,000 (1991). This represents 20% of all construction, installation, and EDIA costs. This

level of contingency is felt to be appropriate for the advanced conceptual design stage of a project with minimal technical risk.

5.6 Other Project Costs (R&D, Pre-operating, Capital Equipment, Conceptual Design, Spares)

Specific R&D required to support the FMI is limited to the areas of the dipole magnet, the 9,000 amp/1,000 volt power supply, the special length quadrupole magnets required at the FMI straight sections, the sextupole magnet, rf power amplifiers (PAs), and 53 MHz vernier cavities. Twelve dipole magnets, two quadrupole magnets and tooling, one sextupole magnet and tooling, two 10 MVA power supplies, three new PAs, and two low voltage, low impedence cavities will be constructed using R&D funds. Total estimated cost of this effort is $11,800K including approximately 30 man-years of ED&I and project management associated with the R&D program. These costs are included in the TPC as is a 37% G&A surcharge, 27% contingency, and escalation.

Pre-operating costs ($3,500K) include the operation of the FMI ring and beamlines during a three month commissioning period. Capital equipment required in support of R&D is estimated at $1,000K.

Prior year costs are now reported in the TPC for this project. These costs ($5,100) include support for all conceptual design work completed through March 1992. Also newly included in the TPC are estimated costs for spares inventories which will be required at the start of operations ($7,800).

5.7 Funding Profiles

Both obligations and cost profiles have been developed based on the construction and installation schedule described in Chapter 6. The profiles are developed at WBS level 3 for all technical and civil components. The project obligations and cost profiles are given in Table 5-4.

Table 5-1: Main Injector Cost Estimate (Dollar amounts in thousands)

WBS	Description			Total
1.	MAIN INJECTOR CONSTRUCTION (TEC)			213300
1.1	Technical Components		79900	
.1	Magnets	41652		
.2	Vacuum	3083		
.3	Power Supplies	10107		
.4	RF Systems	4399		
.6	Kickers & Slow Extract.	2142		
.8	Instrumentation	1649		
.9	Controls	897		
.10	Safety Systems	583		
.12	Utilities & Abort	6419		
.13	Installation	8973		
1.2	Civil Construction		70250	
.1	Phase 1	11330		
.2	Phase 2	49315		
.3	Phase 3	9010		
.4	Phase 4	592		
1.3	Project Management		5910	
.1	Project Management	3561		
.2	Accelerator Physics	1260		
.3	G&A	1085		
1.4	Contingency		31490	
1.5	Escalation		25730	
OTHER PROJECT COSTS (escalation included)				29100
2.	R&D		11840	
3.	Capital Equipment		1000	
4.	Pre-operating		3450	
5.	Prior years conceptual		5100	
6.	Spares		7760	
	TOTAL PROJECT COST (TPC)			242400

Table 5-2: Cost Estimate Labor Codes & Rates ($/hour)

Fabrication		
Technician, Conventional Magnets	T1	29.00
Technician, Accelerator Division	T2	18.70
Technical Support	T3	29.00*
Shops, average capability	S1	33.00*
Shops, specialized/precision	S2	38.00
Installation		
Plumber, steam fitter, sheet metal	IP	41.10
Electrician	IE	38.20
Rigger, crane operator	IG	42.80
Laborer	IL	27.20
Surveyor	IA	31.10
EDIA		
Physicist	PH	33.90
Engineer	EN	32.40
Engineer, Construction Services	CE	40.00*
Designer/drafter	DC	32.00*
Drafter, Accelerator Division	DR	22.20
Programmer	PR	30.90
Project Management	PM	40.00
Architectural Engineering	AE	50.00
Administrative Support	AD	20.00

*Fermilab Service Center chargeback rates

Table 5-3: Total Labor Effort (Man-years, R&D, Pre-Op included)

Fabrication		
Technician, Conventional Magnets	T1	85
Technician, Accelerator Division	T2	61
Technical Support	T3	75
Shops, average capability	S1	4
Shops, specialized/precision	S2	1
Installation		
Plumber, steam fitter, sheet metal	IP	18
Electrician	IE	40
Rigger, crane operator	IG	9
Laborer	IL	2
Surveyor	IA	7
EDIA		
Physicist	PH	38
Engineer	EN	78
Engineer, CES	CE	29
Designer/drafter	DC	43
Drafter, Accelerator Division	DR	35
Programmer	PR	7
Program management	PM	15
Architectural Engineering	AE	45
Administrative support	AD	26
Total		618

Table 5-4: TEC Spending Profiles (Dollar Amounts in Thousands)

Fiscal Year	Obligations		Costs	
	1991	Then-year	1991	Then-year
1992	14467	14997	7811	7975
1993	28046	30004	25652	27062
1994	49344	55003	44909	49445
1995	47464	55002	53944	62089
1996	45629	55000	51536	62049
1997	2599	3277	3697	4662
Total	187500	213300	187500	213300

6. SCHEDULE

It is proposed that the FMI project be completed over the period March 1, 1992 through August 1, 1997. The project schedule is shown in Figure 6-1. The period October 1, 1989 through February 29, 1992 has been devoted to preconstruction R&D and to the completion of all required environmental documentation and the securing of required permits. Preparatory engineering in support of construction is expected to begin on March 1, 1992. The schedule shown reflects that given in the FY93 Construction Project Data Sheets submitted to the Congress in January 1992 and the total manpower estimate shown in Table 5-3. The schedule results in a seven month disruption to HEP operations. This disruption will start on March 1, 1996.

A set of project milestones is given in Table 6-1. As can be seen the FMI ring and 8 GeV beamline can be largely installed without disturbing Tevatron operations. The length of the HEP shutdown is tied to the civil construction in the vicinity of FO and to the effort associated with recycling Main Ring components such as rf cavities and quadrupole magnets. Overall downtime has been minimized by situating the FMI 11 meters away from FO so that commissioning can actually begin prior to completion of construction in this area. Pre-operations with beam are expected to be initiated in August 1996 with Tevatron commissioning starting two months later. Tevatron operations are expected to be initiated in proton-antiproton collider mode with simultaneous slow spill from the FMI.

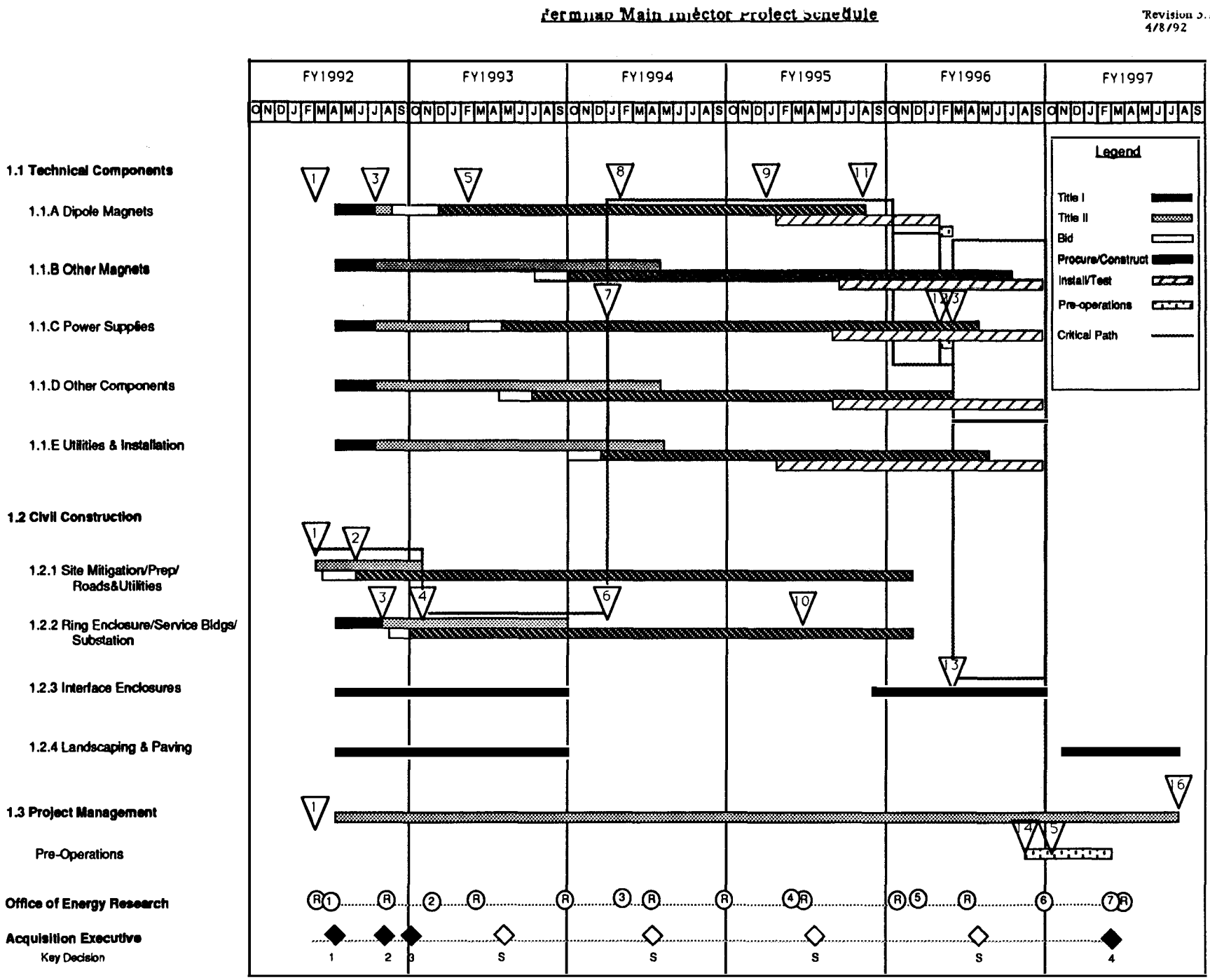


Figure 6-1: Fermilab Main Injector Project Master Schedule

Table 6-1: Major Project Milestones

	Milestone	Date	Description
1992	1	March 1	Start Project
	2	June 15	Award Site Mitigation Contract
	3	July 15	Complete Title 1
	4	November 1	Award MI-60/Enclosure Contracts
1993	5	February 15	Award Magnet Fabrication Contract
1994	6	January 1	Beneficial Occupancy of MI-60
	7	January 1	First Power Supplies Delivered
	8	February 1	25% of Dipoles Delivered
1995	9	January 1	75% of Dipoles Delivered
	10	April 1	Beneficial Occupancy of Ring Enclosure and all Service Buildings
	11	August 15	Last Dipole Delivered
1996	12	February 1	Complete Dipole Power Supply Installation, Start Dipole Power Test
	13	March 1	Complete Dipole Power Test and Start Tevatron Shutdown
	14	August 15	Start Pre-operations with Beam
	15	October 7	Start Tevatron Commissioning
1997	16	August 1	Project Complete

APPENDIX A

SCHEDULE 44

FERMILAB
PROPOSED FY 1994 BUDGET REQUEST
CONSTRUCTION PROJECT DATA SHEET
GENERAL SCIENCE AND RESEARCH - PLANT AND CAPITAL EQUIPMENT
HIGH ENERGY PHYSICS
(TABULAR DOLLARS IN THOUSANDS. NARRATIVE MATERIAL IN WHOLE DOLLARS.)

CHICAGO OPERATIONS
Field Office

FERMI NATIONAL ACCELERATOR

1. Title and Location of Project:
Fermilab Main Injector
Fermi National Accelerator Laboratory, Batavia, Illinois

2. Project No. 92-G-302

3. Date A-E work initiated: 3rd Quarter FY 1992

3a. Date physical construction starts: 3rd Quarter FY 1992

4. Date construction ends: 4th Quarter FY 1997

5. Previous cost estimate: $177,800

6. Current cost estimate: $213,300
Date: April, 1992

7. Financial Schedule:

Fiscal Year	Authorization	Appropriation	Obligation	Cost
1992	$213,300	$15,000	$15,000	$8,000
1993		30,000	30,000	27,100
1994		55,000	55,000	49,400
1995		55,000	55,000	62,100
1996		58,300	55,000	62,000
1997			3,300	4,700
Total	$213,300	$213,300	$213,300	$213,300

8. Brief Physical Description of Project

This project provides for the construction of a new accelerator, designated the Fermilab Main Injector, which will replace the aging Fermilab Main Ring accelerator in all its functions. The Fermilab Main Injector will provide particles for injection into the existing Fermilab superconducting Tevatron accelerator and for direct delivery to the existing fixed target experimental and test beam areas. The accelerator is 3.3 km in circumference and is capable of accelerating protons and antiprotons to 150 GeV. It is constructed using conventional iron core magnets. Also provided are five new beamlines which tie the Main Injector into the existing accelerator complex, transport 120 GeV proton beams to the fixed target experimental areas, and provide particle beams for the testing and calibration of SSC detector components and subsystems.

1. Title and location of Project:
Fermilab Main Injector
Fermi National Accelerator Laboratory, Batavia, Illinois

2. Project No. 92-G-302

The Fermilab Main Injector accelerator will recycle many technical components from the existing Main Ring, including quadrupole magnets, some power supplies and correction magnets, radio frequency (RF) systems, some controls components, and diagnostic devices. The Main Injector will be located on the southwest side of the Fermilab site, tangent to the existing Tevatron at the F-zero straight section.

Specifically provided for in the scope of the project are:

a. Construction of a 3.3 km ring enclosure with service buildings and utilities, and fabrication of new technical components including dipole magnets, high current power supplies, and vacuum systems.

b. Construction of beamline enclosures, service buildings, utilities, and technical components required to implement the 8 GeV Booster-to-Main Injector beamline, the 150 GeV proton and antiproton Main Injector-to-Tevatron transfer lines, and the 120 GeV Main Injector-to-Antiproton Production Target beamline.

c. Construction of technical components required to implement the delivery of 120 GeV beam from the Main Injector to the A-zero Transfer Hall, from which distribution to the existing experimental areas is possible; construction of a new sub-station and 345KV power lines for delivery of electrical power to the Main Injector location.

d. Modifications to the Tevatron ring tunnel at the F-zero straight section for installation of the 150 GeV proton and antiproton transfer lines.

f. Refurbishment and reinstallation in the Main Injector ring enclosure of those technical components which will be recycled from the old Main Ring.

9. Purpose, Justification of Need for, and Scope of Project

The primary purpose of this project is to greatly increase the Tevatron collider luminosity which can be delivered to the two existing collider detector facilities at Fermilab. Fermilab is the only operational high energy physics facility in the world with sufficiently high energy to produce the top quark, the last unobserved fundamental building block forming the basis of our current understanding of the structure of matter. Increasing the luminosity available at the Fermilab Proton-Antiproton Collider to 5×10^{31} $cm^{-2}sec^{-1}$ will maximize the likelihood of discovery of the Top quark if it lies within the range indicated by all present experimental data. The project will also increase the number of protons which can be delivered to the Tevatron for acceleration and delivery to the fixed target experimental areas. Other important purposes of the project are to provide a new capability for 120 GeV beams for fixed target physics research, and to provide year-round beams for the testing and calibration of SSC detector components and subsystems simultaneously with Tevatron collider operations for physics research.

1. Title and location of Project:
Fermilab Main Injector
Fermi National Accelerator Laboratory, Batavia, Illinois

2. Project No. 92-G-302

Increasing the collider luminosity requires increasing the number of protons and antiprotons injected into the Tevatron. The substantial improvement in injection intensities results from the large effective aperture of the Main Injector ring, and from its rapid repetition rate capability. These are achieved through tighter focussing, improved field quality, and the elimination of overpasses which were installed in the Main Ring to accommodate the collider detector facilities. The Main Injector will be capable of accelerating protons to 120 GeV every 1.5 seconds for antiproton production, as compared to a 2.4 second cycle for the present Main Ring. The beam intensity injected into the Tevatron by the Main Injector will approach 6×10^{13} protons per 60 second cycle, which is about two times as great as could be achieved with the Main Ring. The Tevatron proton-antiproton colliding beam luminosity will be increased to at least 5×10^{13} $cm^{-2}sec^{-1}$, which is five times greater than could be achieved using the Main Ring. These performance goals are expected to be reached after some months of operational experience with the upgraded facilities.

10. Details of Cost Estimate

	Item Cost	Total Cost
a. EDI&A at 16.1% of construction costs		$24,600
b. Main Injector construction costs		$152,400
1. Conventional construction	$71,200	
2. Special facilities	81,200	
c. Contingency at 20.5% of above cost		$36,300
Total		$213,300

11. Method of Performance

Design of facilities will be by the operating contractor and subcontractors as appropriate. To the extent feasible construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

CONSTRUCTION PROJECT DATA SHEET

1. Title and location of Project:
Fermilab Main Injector
Fermi National Accelerator Laboratory, Batavia, Illinois

2. Project No. 92-G-302

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12. Schedule of Project Funding and Other Related Funding Requirements

a. Total project cost	Prior Years	FY1992	FY 1993	FY 1994	FY 1995	FY1996	FY1997	TOTAL
1. Total facility costs								
(a) Construction line item	$0	$8,000	$27,100	$49,400	$62,100	$62,000	$4,700	$213,300
Total facility cost	$0	$ 8,000	$27,100	$49,400	$62,100	$62,000	$4,700	$213,300
2. Other project costs								
(a) R&D costs necessary to complete construction (G&A included)	$5,400	$3,700	$4,100	$3,200	$500	$0	$0	$16,900
(b) Pre-operating costs	$0	$0	$0	$0	$0	$1,600	$1,800	$3,400
(c) Capital equipment	$0	$200	$200	$200	$200	$100	$100	$1,000
(d) Inventories and Spares	$0	$0	$0	$0	$4,300	$3,500	$0	$7,800
Total other project costs	$5,400	$3,900	$4,300	$3,400	$5,000	$5,200	$1,900	$29,100
Total project costs	$5,400	$11,900	$31,400	$52,800	$67,100	$67,200	$6,600	$242,400

b. Total related incremental annual funding requirements (estimated life of project: 20 years)

1. Power costs for Main Injector slow spill operations	$5,400
2. Experimental Areas operating costs with 120 GeV slow spill beam	$1,200
Total incremental annual funding	$6,600

13. Narrative Explanation of Total Project Funding and Other Related Funding Requirements

a. Total project costs
1. Total facility cost
(a) Construction line item - explained in items 8, 9, 10.
2. Other project costs
(a) Direct R&D operating costs - This provides for project conceptual design activities, for design and development of new components, and for the fabrication and testing of prototypes. R&D on all elements of the project to optimize performance and minimize costs will continue through early stages of the project. Specifically included are development of the high current dipole magnet, the associated power supply system. A small number of dipole magnets and power supplies will be fabricated and tested using R&D operating funds.

(b) Pre-operating costs - Includes personnel and power costs for a several month commissioning period.
(c) Capital equipment - Includes test instruments, electronics, and other general equipment to support 12.a.1 and 2.
(d) Inventories and Spares - Provides for special process spares for the major technical components, primarily magnets and power supplies, and for an increase in common use inventories for Main Injector related items.

b. Total incremental funding requirements - It is assumed that the Fermilab Tevatron complex will continue to operate both the fixed target and collider programs, with each running about 40% of the time. The Main Injector replaces the existing Main Ring in all its functional roles and it is designed to require nearly the same amount of power to operate for those purposes. The new Main Injector capability for test beam operations simultaneously with Tevatron operations for physics research will require an average increase in power plus other operating cost of about $6.6M annually. The increase in operating costs in 12.b.1 and 2 reflects solely the incremental demands of delivering 120 GeV protons to the fixed target experimental areas during Tevatron collider operations.

14. Incorporation of Fallout Shelters in Future Federal Buildings

Not specifically incorporated into this project as sufficient space is available at other locations on the site.

15. Incorporation of Measures for the Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities.

The total estimated cost of this project includes the cost of those measures necessary to assure the facility will comply with Executive Order 12088. A Section 404 permit from the Army Corps of Engineers will be required prior to initiation of civil construction.

16. Evaluation of Flood Hazard

This project will be partially located in the flood plain of Indian Creek, which originates on the Fermilab site. An active drainage system will allow the control of water levels within the region encompassed by the Main Injector ring. Measures will be taken to insure that the water retention capacity of the Indian Creek drainage basin is maintained both during the construction and operational phases of the project. Components installed in the underground Main Injector ring and beamline enclosures will be protected by pumps, as are all existing underground enclosures on the Fermilab site. Service buildings and enclosure access points will be located well above the floodplain. Construction will be in accordance with Executive Order 11988. An Army Corps of Engineers permit will be obtained prior to initiation of civil construction.

1. Title and location of Project:
Fermilab Main Injector
Fermi National Accelerator Laboratory, Batavia, Illinois

2. Project No. 92-G-302

17. Environmental Impact

Environmental documentation is being prepared for this project. Any wetlands that will be disturbed during the course of the project will be restored as closely as possible to their original condition. Mitigation plans for any disturbance and/or loss of wetlands will only be finalized after consultation with the Corps of Engineers. Compensatory wetlands will be created in the vicinity of the disturbed wetlands in a ratio of 1-1/2 to 1 of existing wetlands impacted by construction of the Main Injector site. The project will be in compliance with the National Environmental Policy Act.

18. Accessibility to the Handicapped

All tunnel enclosures and service buildings are occupied only temporarily. They do not provide permanent working space, and are considered hazardous areas with restricted access under laboratory policy. As such, no special measures for accessibility to the handicapped will be provided in these areas. The office areas of Industrial Building 5 are accessible to the handicapped.

APPENDIX B

PROJECT BASIC DATA FOR

FY94 VALIDATIONS

PROJECT BASIC DATA
for
FY94 VALIDATIONS

Program:	High Energy Physics Fermi National Accelerator	Status of Design: Conceptual - 100%
Project:	Fermilab Main Injector	Title I - 2% Title II - 0%
Project No:	BAKALIA 92-G-302	

(Program Office Assigned number only, if available)

TEC:

The TEC is $ 213.3M
ED&I is 12.1% of Construction Cost
(Excluding construction management and project management at 4.0%)
Contingency: 20.5% of Design and Construction Cost.

Project Description and Background:

This project provides for the construction and installation of a new Main Injector Accelerator to replace the 150 GeV Fermilab Main Ring conventional accelerator. The purpose of this part of the project is to increase collider luminosity,to increase fixed target intensity, improve collider detector performance by the removal of a major source of background, and to provide a fixed target test beam at approximately 120 GeV during collider operation. An additional possible benefit is a future high duty factor Kaon production capability. A new tunnel for the 150 GeV Main Injector, with associated beamlines, extraction systems and an abort system will be constructed adjacent to the existing Tevatron Tunnel.

About 15,000 ft of tunnel and 51,300 (net 43,000) sq ft of service buildings will be constructed. Technical components for the Main Injector and the beamlines and beam transfers include conventional magnets and accelerator components. Some reuse of technical components from the existing Main Ring is included in the design of the Main Injector and extracted beam lines. The project includes the construction of service buildings, tunnel enclosures, standard and accelerator utilities, and new conventional magnets, expecially the main bending dipoles for the Main Injector.

Environmental documentation has been prepared, and approvals will be received prior to the start of the project.

FY94 Budget Authority (B/A):

The request is for $ 55.0M for FY94.
This request is to cover more civil construction and to continue procurement for magnet and accelerator systems components for the conventional Main Injector accelerator.

Specifically, this request covers authority to fund bid packages to continue the Main Injector site work, beam enclosures, utilities, and service buildings.

The FY93 request was $30M; prior year funding was $15M.

Technical/R&D:

There is no particularly unusual construction in the beamlines and Main Injector. The Main Injector dipoles are a new, conventional, design however, and R&D is being carried out to obtain tooling and to prototype the new magnets and accelerator components. The Main Injector and the beamlines make extensive use of existing accelerator magnets and technical components.

Additional R&D costs are associated with power supplies for the new high current main dipoles, special length quadrupoles, and new rf power amplifiers.

The risk of this project is low for a project of this type. The Fermilab staff is experienced in all aspects of this project; it is similar to the recently completed TeV I project in technical scope and detail.

Schedule:

Title I design start scheduled 3QFY92.
Title I and II design duration: 33 months total.
Procurement and construction start scheduled:
2QFY92, 3QFY92.
Procurement and construction complete: 4QFY97

Status of Documentation:
(For major projects and major systems acquisitions only)

Justification for New Start:	Approved 07/17/90	(mm/dd/yy)
Project charter:	Approved __/__/__	(mm/dd/yy)
Project Plan:	Approved __/__/__	(mm/dd/yy)

Additional Information:

An Environmental Assessment has been submitted.

Contingency factor used is 20.5%. This is an overall factor and has been split for varying degrees of certainty in the different components of the work breakdown structure. The analysis has been carried to the 4th level for the technical components and to the third level for the civil construction. This overall contingency is appropriate for the present level of the conceptual design. As the design continues, it will probably become appropriate to allocate additional varying contingency factors as certainties become better determined.

FY94 FERMILAB MAIN INJECTOR

PROJECT VALIDATION CHECKLIST

I. OBJECTIVES

Fermilab Main Injector (FMI) project objectives and performance parameters have been developed to support the programmatic needs and goals of the laboratory. These have been defined in the light of much experience and a number of studies which have been made to understand the current limitations of the accelerator and how to improve the performance and utilization of the accelerator in order to support the High Energy Physics program in future years. Additional information has been supplied to the Validation Review Committee.

II. SCOPE

A. REQUIREMENTS

1. Facility Performance Requirements

Fermilab has kept both the High Energy Physics Program Office and the Batavia Area Office fully informed of the goals for the FMI and the improvements expected. There is a mutual understanding of the programmatic needs for the FMI project.

2. Facility Requirements

The general requirements for the facility both in terms of real property, buildings and hardware have been defined at the conceptual level of design. Materials documenting these requirements have been distributed to the Validation Review Committee.

3. General Design Criteria - DOE Order 6430.1A

a. The total estimated cost of the project includes the cost of those measures necessary to assure the facility will comply with DOE 6430.1.

b. Design of technical items is based upon much local experience including recent projects such Tevatron I, Tevatron II, the Fermilab Linac Upgrade, and the Tevatron superconducting accelerator.

c. A PSAR for the Fermilab Main Injector has been prepared and appropriate reviews will be scheduled.

4. Safeguards and Security Requirements

Advice and guidance from cognizant safeguards and security personnel will be utilized during the project planning and design stages. Any radiation hazards that are known to exist will be treated in the same manner as the hazards are now treated in the present operating complex under Accelerator Division control. The facility does not involve items of a classified nature. Physical security will be provided in the same manner as that currently existing in the accelerator facility.

5. Location

Location is determined, to a large extent, by the existing beamlines and accelerator enclosures and technical requirements. Basically, three alternative locations were considered for the FMI. The area selected best fits both the technical requirements and provides the best site from a civil engineering perspective. Also, during the preparation of the Environmental Assessment for the FMI, alternative locations were reviewed and the area selected was shown to have the least environmental impact, thereby minimizing mitigation requirements. The project is in compliance with the overall Site Development and Facilities Utilization Plan. Land acquisition is not required.

6. Function Definitions

Functions of all major structures, systems and components are defined to the extent appropriate for a conceptual design. Considerations of value engineering techniques have also been included at a level appropriate to conceptual design, and R&D is proceeding on critical elements.

7. Procurement Requisition Strategy

The CH/BAO is working with Headquarters and FMI Project Management to create a Business Strategy Group to consider major procurement strategy.

8. Matching of Existing Facilities to Demands

To the largest extent possible, available utilities, roads and accesses and other support facilities will be used. In particular, extensive use will be made in the FMI of utilities relocated from the present Main Ring, such as transformers, and heat exchangers, as well as some of the technical components. Utilities and Roads to be installed during project construction as part of the project are sufficient for the maximum loads associated with full operation.

9. Initial Complement of Equipment

The requirements for the initial complement of equipment for the FMI Accelerator have been defined. Cost estimates for this accelerator equipment have been made based on similar equipment installed at Fermilab.

10. Quality Levels and Program Requirements

The quality levels and program requirements have been defined by many years of operation of the present facility. The levels and requirements have been incorporated into the conceptual design and cost estimate.

11. Emissions and Wastes

Emissions and wastes will be no different than those occurring in the presently operating accelerator. Total compliance with Federal and State emission and waste regulations will not be a problem.

12. Codes and Standards

The facility will operate within applicable local, state and national codes and standards. Compliance with DOE general design criteria 6430.1A will be maintained.

13. Office space

Office space is not required for the Main Injector project.

14. Space Requirements

Space for tunnel and equipment enclosures is in addition to current space. Where possible current equipment and tunnel enclosures will be utilized. In the single instance where construction of the FMI requires the demolition of an existing above grade structure, the space required is replaced in the scope of this project.

At the F0 (rf) straight section part of the rf building must be demolished in order to construct the modified tunnel enclosure at the injection point for 150 GeV protons and antiprotons to be delivered from the FMI to the Tevatron. Also, beamlines carrying 120 Gev protons to the antiproton target at AP-0 and to the Test Beam Line, and 8 GeV antiprotons from the Accumulator to the FMI traverse this region. When completed, two connected buildings, the reconfigured F0 rf building and a FMI Service Building MI-60 will house the rf systems for accelerators in both enclosures, and also beam transfer and extraction equipment for equipment to be located in the F0 and MI-60 locations in the respective tunnels.

15. Environmental Assessment

An Environmental Assessment has been prepared and submitted to DOE headquarters, with the publication of a draft FONSI (Finding of No Significant Impact) expected. All necessary environmental permits from federal, state, and local agencies have been issued.

16. Energy Efficiency

Energy efficiency has been a consideration as demonstrated in the FMI dipole magnet design. All other areas of design have also employed energy efficiency as a criteria.

17. Construction Project Data Sheets

Construction Project Data Sheets for the FMI Project have been submitted.

18. Maintainability Objectives

Maintainability, based upon years of experience of accelerator operation at Fermilab, has been a consideration in all areas of civil and technical design.

19. Identification of Maintainability Issues

Both technical and civil maintenance organizations have been consulted throughout the conceptual design effort, and will participate in the Title I/II designs and specifications.

20. Utility Acquisition and Management

Electrical power is the only commercially purchased utility service required for the FMI. Power and services will be provided as set forth in existing DOE contracts with Commonwealth Edison Co., and as negotiated by DOE in future years.

B. DESIGN (Conceptual, Title I, Title II)

1. Design Status

A complete conceptual design exists at this time. In addition, work performed by Envirodyne Engineers, Inc. and Fluor Daniel under a State of Illinois Challenge Grant has generated a complete bid package for the FMI site wetlands/floodplain mitigation. Fluor Daniel has been selected as the A&E firm for the FMI project. The bid package mentioned above is the basis for the US Army Corps of Engineers approval of the work necessary for compliance with the wetlands permit. Additional

advanced conceptual design funded by the Illinois Challenge Grant is under contract with Fluor Daniel. DOE approval to begin Title I work for the FMI, under contract with Fluor Daniel, has been received.

Studies for the conceptual design and cost estimate have been made based upon current experience, and general civil engineering practices. All major items have been scoped. The scope has been well defined from the programmatic requirements of the Laboratory. The FMI project has been included in the current Fermilab Site Development and Facility Utilization Plans. The schedule has been developed using time estimates based on similar work performed at Fermilab on projects of comparable nature. The FMI involves the construction of some new components and the relocation of some existing Main Ring components, and is similar in nature to numerous modifications made to the Main Ring in recent years. The FMI dipoles have been designed and prototyping started in FY90. This work is similar to the production of conventional magnets for the Antiproton Source. Cost and schedule projections are based heavily on similar recent experience.

The Conceptual Design and/or accompanying cost estimate includes:

- -site development plans including utilities
- -building layouts
- -major equipment arrangements, above and below grade
- -piping and instrumentation line drawings
- -process and heating, ventilation, and air conditioning layouts as appropriate
- -electrical single line diagrams
- -major mechanical, electrical, and experimental equipment lists, etc.
- -selected utility supply discussion
- -compliance analyses

2. Scope Changes

Some scope changes have been included since the last validation. These changes have been presented to DOE review panels. These changes in scope include: a) ES&H driven refinements of design such as:

i) Increased passive radiological shielding (approximately $11M in cost)

ii) Fire protection systems (approximately $2M in cost)

b) Change in magnet procurement strategy. resulting in the removal of the "IB-5" Assembly Building, including associated EDI&A (approximately $3M cost reduction)

The largest item, the increased passive shielding, is the result of a complete review of radiological shielding at Fermilab carried out during 1991, and the desire to make the FMI

consistent with the policies and practices adopted for the Fermilab site in conformance to general DOE directives. During the preparation of the FMI PSAR, it became clear that conformance to DOE directives would require the fire protection additions, which are more than provided for existing facilities on the Fermilab site at present. The removal of "IB-5" is in conformance with a decision that most of the FMI dipoles will be purchased complete from industry.

3. Site Conditions

Soil borings were available for areas in close proximity to the site considered. In addition, new borings have been made specifically in support of the conceptual design, the Environmental Assessment, and the wetlands mitigation bid package. Recent nearby construction experience (TeV I) has been used to help prepare cost estimates.

4. Safety hazards and Risks

Hazards and risks are characteristic of those already encountered in the accelerator complex and its construction. No new unique hazards are expected.

5. Value Engineering - Design Cost Effectiveness

The design is cost effective at a conceptual design level. Further studies to minimize cost and lifecycle costs will be carried out in parallel with the Title I design. In particular, specific attention will be paid to the design of the area where the proton and antiproton injection lines into the Tevatron from the FMI connect to the Tevatron at F0. Optimization of beam transport line design has been done, resulting in the saving of more than $1M in 8 GeV line transport dipoles.

6. Environmental Documentation

Environmental documentation has been prepared. All necessary permits have been received from appropriate local, state, and federal agencies. In particular, a Corps of Engineers permit was required and has been obtained. The Environmental Assessment has been submited to DOE and a publication of a draft FONSI (Finding of No Significant Impact) is expected.

The environment surrounding the proposed construction site has been characterized to the extent that the entire Laboratory site is characterized. Topology and hydrology are documented. The impact of the proposed facility on the environment will be no different from the existing facility; no unique hazards are expected. To be noted is the flow of Indian Creek through the proposed site of the Main Injector. Care will be taken to

provide proper creek drainage as required in the Corps of Engineers permit.

Both wetlands and water retention areas in locations classified as floodplains will be preserved in quantity and character as required by the Corps of Engineer permit.

Sites classified as of archeological interest will be taken into account in the final design. There are no sites impacted by the construction.

7. Prerequisite R&D

The necessary R&D required to design and specify the basic system has been done. Additional R&D is in progress to refine the design. R&D is underway as required to work out detailed designs and to support prototype fabrication of the FMI main dipoles and of special components. These activities will continue to help refine the requirements that are necessary for specifying and accomplishing the construction of special facilities. Some R&D may be necessary to support fabrication of the FMI main dipoles in quantity after prototyping is complete. A schedule for all the required R&D costs so far identified has been provided in the project data sheets. R&D funding will be required for detailed design, tooling, prototype fabrication, and production development for the FMI main dipoles and other necessary special components, including power supplies.

8. Participants

The conceptual designs presented to the Validation Review Committee have been prepared by Fermilab staff members. In particular, members of the Accelerator Division, Technical Support Section, and Facilities Engineering Services have participated in the designs for the FMI accelerator and associated beam lines. Also, Envirodyne Engineers, Inc. and Fluor Daniel have participated, under the State of Illinois Challenge Grant, in the preparation of the wetlands mitigation bid package. Fluor Daniel has participated in advanced conceptual design and the complete civil cost estimate. This work was also done under the Illinois Challenge Grant.

9. Uncertainties.

The FMI main dipole magnets are conventional, not superconducting, magnets. Their fabrication should be similar to recently 'in-house' constructed TeV I magnets. The decision to contract for construction by industry of the complete dipole magnet assemblies will require stringent quality control, as well as careful technology transfer. The civil construction techniques are similar to previous work on the Fermilab site.

Thus, there are no unique aspects to this proposal. The 9,000 ampere power supplies necessary for the FMI dipole bend bus might be classified as unusual, but are not regarded as technically unique.

The acceptance of the Environmental Assessment and the publication of the FONSI could impact the start of construction.

10. Energy Conservation Report

An energy conservation report will be prepared during Title I/II.

11. Maintainability Considerations

Maintainability concerns have been considered and addressed during the conceptual design. Items considered include:

- -accessibility
- -operator/user friendly
- -documentation
- -standardization/interchangeability
- -flexibility
- -desirable levels of quality.

Project Management has directly participated in reviews of these items.

12. Performance Standards for Hi-Rise buildings

Although no structure has a second story, all buildings will follow mandatory code for energy conservation.

III. SCHEDULE

All of the following factors have been considered at a depth appropriate at this conceptual design level in developing the schedule.

- milestone responsibilities
- budget cycle timing
- contractor selection duration
- Headquarters review and approvals
- prerequisite R&D schedule constraints
- dependency upon timing and amount of operating funds
- historical experience on design, procurement, and construction durations, NEPA documentation, etc.
- development of environmental documentation
- procurement lead times for equipment (particularly reflecting vendor quotes)
- logical sequence of design, procurement, and construction
- reasonable manpower levels, buildup and rampdown
- reasonable obligation and costing rates
- shift work or overtime work requirements

- work space constraints
- exposure constraints
- operational constraints
- maintainability reviews
- maintainability deliverables
- milestone dictionary

The construction schedule falls into three distinct phases. In the first phase, site preparation and wetlands mitigation will be completed.

In the second phase, the large majority, if not all, of the FMI main dipoles will be fabricated, and the entire FMI ring tunnel enclosure constructed, as well as most of the beam transport lines. This conventional construction will include all of the FMI above ground facilities as well, with the exception of the work on the Tevatron side at F0. As occupancy becomes possible, the main dipoles may be set in place in the FMI. During this phase the fabrication of the new main dipoles will be the critical path.

During the above two phases, the existing accelerator complex will be maintained fully operational.

During the third phase the accelerator complex will be shut down. Civil construction of the F0 tunnel enclosure, following demolition and removal of the existing enclosures, will be the critical path item. Main dipole fabrication will conclude, and installation of the main dipoles will be completed. Civil construction of those portions of the beam transport lines left unfinished in the first phase will be undertaken and completed. Installation of technical components to be removed from the existing Main Ring conventional accelerator can proceed in parallel in the FMI tunnel enclosure and Service Buildings. Reinstallation of components in the Tevatron F0 area, and the completion of installation of components in the F0 connecting and adjacent beam transport lines must await completion of the conventional construction. Since the FMI itself can be operated entirely within the new FMI tunnel enclosure, commissioning of the FMI can begin upon completion of installation of FMI components but prior to completion of the Tevatron F0 reinstallation.

IV. Estimate

A. General

1. Estimate Preparation

The estimates presented were prepared in March 1992. The cost estimate is done in FY91 base year dollars with the escalation shown in "year of expenditure" dollars.

2. Estimate Basis

Estimates are based upon conceptual design layouts, preliminary engineering calculations, and experience with similar projects done at Fermilab. Our recent experience with the TeV I construction project forms the basis for a large fraction of the cost estimate for this project. For construction, estimates are based on quantity takeoffs where available and square foot estimates. Cost comparisons have been made with specific portions of recent similar Fermilab construction such as Transfer Hall Addition, Booster Laboratories, Industrial Center Building, civil construction for the Linac Upgrade Project, and several of the Tevatron I and II buildings. The cost estimate methodology is adapted from that used to estimate the Superconducting Super Collider (SSC) injection system as incorporated into the SSC Conceptual Design Report. Manpower estimates where appropriate have been derived from the TeV I project, and recent experience (1988) on modification and reinstallation of Main Ring components has also been considered.

3. Support of Estimates

In most cases, vendor quotes are not appropriate at the conceptual level for this design. In some cases, however, such as for components of the FMI dipole magnets, and in support of parts of the civil estimates, vendor quotes have been solicited. Catalogue prices have been used for components where appropriate. Manpower rates are based on present Fermilab Accelerator tech experience, Fermilab chargeback rates, or T&M trade rates. Commercially published construction data bases such as R. S. Means, have been used very successfully at Fermilab for cost estimation.

4. Contingency

The contingency reflects the degree of confidence in the scope of work, development features, pricing methodology, and complexity of the project. The contingency analysis provides for a varying degree of uncertainty in the different components of the Work Breakdown Structure.

5. Escalation Rates

Escalation rates provided by DOE were used. The most recent information obtainable was dated February 1992.

6. Project Reviews

This is the third cost estimate submitted to DOE for this project and is a bottoms up estimate. It has been reviewed by knowledgeable Fermilab staff and management. It has also been

reviewed by a DOE/ER program committee. An Independent Cost Estimation (ICE) review was presented in early 1991 to verify estimating and conceptual design criteria used in estimation. This estimate was prepared in March 1992.

7. Uniqueness

The technical components and civil construction are similar to work that has already been done at Fermilab and are therefore not unique. The 9,000 ampere power supplies for the FMI dipole bus are unusual, however.

8. Estimating Guides

Conventional construction items and standard equipment estimates were made using standard estimating guides. Square foot estimating data available from commercial publishers (Means & Richardson) have been used where applicable. Also, information available to Fluor Daniel, the A&E firm for the FMI project, in their in-house estimating references was incorporated.

9. Indirect Costs

All known indirect costs have been included in the estimate.

10. Title I/Title II Estimates

Only the wetlands mitigation bid package, prepared with funds from a State of Illinois Challenge Grant, is presently beyond a conceptual design stage.

11. Experimental Components

Experimental detector improvement costs for the CDF and DO detectors are not included in the estimate. Detector upgrades are usually incorporated in the ongoing laboratory capital equipment expenditure profile.

12. Procurement Strategy

To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids. As presently planned, dipole magnet construction will be done by a commercial vendor, rather than at Fermilab as was the case for the TeV I project.

13. Life Cycle Costs

Materials and systems selections, especially with respect to maintainability, are based on life-cycle costs.

14. Maintainability

Maintainability issues have been specifically identified.

15. Costs are properly applied

Total Estimated Costs and Total Project Costs definitions have been properly applied and reflect proper financial management.

B.Construction

1. Bulk Materials

Both engineering drawings and past experience were used to estimate the bulk material quantities. Also, experience of the A&E firm, Fluor Daniel, was incorporated.

2. Quantity Growth

Normal estimating methods for conceptual estimates allow for quantity growth.

3. Bulk Material Pricing

The bulk material costs are current and reflect local conditions.

4. Labor Costs

Labor estimates are based on (Davis-Bacon) local rates where applicable and at actual average rate for component fabrication and include applicablefringe and other hidden costs. Costs have been derived from the Tevatron I Project. The local labor market has critical skill construction labor available.

5. Equipment Pricing

Equipment Pricing is based upon actual experience in the Tevatron I Project, the Linac Upgrade Project, other Fermilab construction, and on commercially published cost data.

6. Indirect Costs

Indirect construction costs have been included.

7. Labor Productivity

Labor productivity is based on much local experience.

8. Labor Availability

All necessary craft labor is available in the Chicago area. This is not a classified project.

9. Pricing variants

To the extent required for the conceptual design, the cost estimate reflects code, QA, scheduling, climatic, geographic, and other unique specification requirements.

10. Unitized Pricing

Not applicable.

11. Operational Costs have been Estimated

Incremental costs for the operation of this facility have been calculated and are included in the Project Data Sheets.

12. Transition Plan

A transition plan will be developed in more detail as Title I/II packages are developed.

C. Engineering and Management

1. ED&I Guidance

ED&I has been estimated using methods the DOE review panels have accepted.

2. Contractor Project Management

Contractor project management and engineering costs are included in the EDIA.

3. EDIA Estimate

EDIA costs are estimated as the same percentage of construction costs in consultation with the A&E firm and as was done for the recently completed Tevatron I Project and current Linac Upgrade Project at Fermilab.

4. Inspection

Inspection, QA, and QC costs have been included. When these costs are part of Laboratory G&A, that has been considered.

5. Management

Fermilab has considerable experience with Program Management Control systems as used in TeV I and II. We consider the management system responsible for this activity to be mature and reasonable. Adequate personnel will be made available. A CSCS system has been prepared.

6. Change Control

A draft of the change control system has been developed and submitted for comment to DOE CH/BAO. Project baselines are in process of being established with DOE.

D. Stewardship of the Facility

1. Post Occupancy Operations

Provision for increased power costs have been included in out-year laboratory operating budget requests, reflecting the increased operating schedule made possible by the FMI project.

In general, regular operating expenditures will not rise because the FMI will replace the Main Ring Accelerator, and expenditure due to the Main Ring operations will cease.

2. Support Resources

Staff presently used in support of the Main Ring will be reassigned in support of the Main Injector.

3. Rationale

As noted, when the FMI is operational, the Main Ring is decommissioned, and except for power costs, other operational costs and the number of support personnel are expected to remain constant.

V. Funding and Costs Status

1. Basis for the Planned Authorization, Appropriation, and Cost Schedule.

The programmatic goal of the FMI project is to achieve an improvement in Collider luminosity, an improvement in Fixed Target intensity, and to provide for the operation of test beams in approximately one half of the fixed target areas during Collider operation. This goal has been set by the demands of the physics experimental program. Increased luminosity in the mid 1990's time scale is crucial to productive utilization of the Tevatron. This increased potential is necessary for a viable national high energy physics program in the pre-SSC era. The test beam capability

is vital to the development of detector technology for the SSC era. The construction of this authorized project at the earliest possible time is urged. The appropriation and obligation schedule is predicated on issuing the long-lead contracts at the earliest possible time. The costing is based on an estimate of the effort done as a function of time. The schedule calls for a shutdown of the order of seven months for moving those Main Ring components to be reused into the FMI, and to accomplish the civil construction in the FO area. In order for this shutdown to be utilized effectively all the civil construction for the FMI ring and almost all of the beam transport line civil construction, and almost all of the FMI main dipoles must be complete prior to the shutdown. Thus, a significant fraction of the funding is required prior to shutdown. Any delay in authorization or appropriation will result in extending the time to operation.

2. Other Associated Project Costs

Other associated project costs include $ 29.1M R&D, preoperation, spares, and capital equipment costs. When the project is complete there is expected to be a related annual funding increase for operating and improvement costs. These include cryogenic (in the test beams) and power costs, personnel and M&S costs totaling $ 6.6M, of which $ 1.2M is directly related to the operation of the test beam in the fixed target area. It is estimated that no additional people will be required to maintain and operate the facility.

3. Funding Consistency

The annual funding proposed is consistent with the project schedule. The schedule has been developed on the basis of a preliminary Critical Path Network (CPN). The CPN will be revised, updated, and expanded as the R&D, design, and project advances.

4. Continuing Resolution Alternatives

In the event of a continuing resolution, the project will be delayed proportionally.

5. Incrementally Funded Construction Contracts

None.

6. Funding by Client or Consultant Agencies

Not applicable.

7. Energy Conservation Funding

No reduction of energy conservation or maintainability items has occurred.

APPENDIX C

EVNIRONMENTAL AND SHIELDING CONSIDERATIONS

(NOT INCLUDED)

APPENDIX D

LATTICE FUNCTIONS

Linear lattice functions for beam line: MI17 Range: #S/#E

delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
MI60		0.000	9.811	-0.026	0.000	0.000	0.000	-0.057	0.000	62.422	-0.040	0.000	0.000	0.000	0.000	0.000
Q605	D	0.000	9.811	-0.026	0.000	0.000	0.000	-0.057	0.000	62.422	-0.040	0.000	0.000	0.000	0.000	0.000
Q604	F	17.289	59.382	-0.025	0.127	0.000	0.000	-0.098	0.002	11.099	0.064	0.114	0.000	0.000	0.000	0.000
Q603	D	34.577	10.318	0.027	0.250	0.000	0.000	0.000	0.006	54.981	0.045	0.237	0.000	0.000	0.000	0.000
Q602	F	51.866	56.249	0.024	0.377	0.000	0.000	0.097	0.002	10.148	-0.060	0.368	0.000	0.000	0.000	0.000
Q601	D	69.155	9.839	-0.028	0.508	0.000	0.000	0.057	0.000	62.044	-0.049	0.489	0.000	0.000	0.000	0.000
BENDDS_1		71.394	12.335	-0.913	0.542	0.000	0.000	0.061	0.003	52.036	3.187	0.495	0.000	0.000	0.000	0.000
BENDDS_2		75.458	22.211	-1.517	0.581	0.000	0.000	0.103	0.017	29.665	2.317	0.512	0.000	0.000	0.000	0.000
BENDDS_1		75.817	23.321	-1.571	0.584	0.000	0.000	0.109	0.017	28.028	2.240	0.514	0.000	0.000	0.000	0.000
BENDDS_2		79.882	38.541	-2.175	0.605	0.000	0.000	0.207	0.031	13.364	1.368	0.547	0.000	0.000	0.000	0.000
Q532	F	82.121	45.045	0.251	0.614	0.000	0.000	0.265	0.016	9.149	0.366	0.581	0.000	0.000	0.000	0.000
BENDDS_1		84.360	36.541	2.548	0.622	0.000	0.000	0.277	0.000	9.699	-0.433	0.620	0.000	0.000	0.000	0.000
BENDDS_2		88.424	19.216	1.715	0.647	0.000	0.000	0.305	0.014	15.234	-0.929	0.674	0.000	0.000	0.000	0.000
BENDDS_1		88.784	18.010	1.641	0.650	0.000	0.000	0.310	0.014	15.918	-0.973	0.678	0.000	0.000	0.000	0.000
BENDDS_2		92.848	8.058	0.808	0.705	0.000	0.000	0.394	0.028	25.845	-1.469	0.710	0.000	0.000	0.000	0.000
Q531	D	95.087	5.985	0.018	0.758	0.000	0.000	0.474	0.053	30.415	0.078	0.722	0.000	0.000	0.000	0.000
BENDDS_1		97.327	7.883	-0.763	0.812	0.000	0.000	0.639	0.084	25.221	1.586	0.735	0.000	0.000	0.000	0.000
BENDDS_2		101.391	17.400	-1.579	0.869	0.000	0.000	1.008	0.098	14.626	1.020	0.769	0.000	0.000	0.000	0.000
BENDDS_1		101.750	18.561	-1.651	0.872	0.000	0.000	1.043	0.098	13.911	0.970	0.773	0.000	0.000	0.000	0.000
BENDDS_2		105.814	35.294	-2.467	0.897	0.000	0.000	1.468	0.112	8.328	0.403	0.834	0.000	0.000	0.000	0.000
Q530	F	108.054	43.544	-0.252	0.906	0.000	0.000	1.648	0.016	7.884	-0.360	0.880	0.000	0.000	0.000	0.000
BENDDS_1		110.293	37.301	2.092	0.915	0.000	0.000	1.536	-0.082	11.931	-1.323	0.918	0.000	0.000	0.000	0.000
BENDDS_2		114.357	22.677	1.506	0.937	0.000	0.000	1.231	-0.068	26.487	-2.259	0.955	0.000	0.000	0.000	0.000
BENDDS_1		114.717	21.613	1.454	0.940	0.000	0.000	1.207	-0.068	28.140	-2.341	0.957	0.000	0.000	0.000	0.000
BENDDS_2		118.781	12.172	0.869	0.980	0.000	0.000	0.959	-0.054	50.968	-3.275	0.974	0.000	0.000	0.000	0.000
Q529	D	121.020	9.851	-0.007	1.014	0.000	0.000	0.876	-0.002	61.508	-0.107	0.980	0.000	0.000	0.000	0.000
BEND_1		123.389	12.067	-0.709	1.049	0.000	0.000	0.939	0.035	52.969	2.251	0.987	0.000	0.000	0.000	0.000
BEND_2		129.485	25.331	-1.468	1.106	0.000	0.000	1.216	0.056	29.761	1.555	1.011	0.000	0.000	0.000	0.000
BEND_1		129.844	26.402	-1.512	1.108	0.000	0.000	1.236	0.056	28.659	1.514	1.013	0.000	0.000	0.000	0.000
BEND_2		135.940	49.464	-2.271	1.135	0.000	0.000	1.640	0.077	14.464	0.814	1.062	0.000	0.000	0.000	0.000
SF		136.864	53.765	-2.386	1.138	0.000	0.000	1.711	0.077	13.058	0.708	1.072	0.000	0.000	0.000	0.000
Q528	F	138.309	58.247	-0.021	1.142	0.000	0.000	1.781	0.001	11.794	0.044	1.091	0.000	0.000	0.000	0.000
BEND_1		140.677	49.648	2.237	1.149	0.000	0.000	1.643	-0.076	14.008	-0.708	1.121	0.000	0.000	0.000	0.000
BEND_2		146.773	26.872	1.500	1.175	0.000	0.000	1.246	-0.055	26.622	-1.360	1.172	0.000	0.000	0.000	0.000
BEND_1		147.133	25.810	1.456	1.178	0.000	0.000	1.227	-0.055	27.614	-1.399	1.174	0.000	0.000	0.000	0.000
BEND_2		153.229	12.549	0.719	1.233	0.000	0.000	0.957	-0.034	48.631	-2.048	1.201	0.000	0.000	0.000	0.000
SD		154.152	11.323	0.608	1.245	0.000	0.000	0.926	-0.034	52.505	-2.147	1.204	0.000	0.000	0.000	0.000
Q527	D	155.597	10.282	0.008	1.267	0.000	0.000	0.897	0.004	56.395	0.110	1.208	0.000	0.000	0.000	0.000
BENDDS_1		157.837	12.655	-0.885	1.299	0.000	0.000	0.986	0.057	46.698	3.006	1.215	0.000	0.000	0.000	0.000
BENDDS_2		161.901	22.174	-1.457	1.338	0.000	0.000	1.248	0.071	25.811	2.134	1.234	0.000	0.000	0.000	0.000
BENDDS_1		162.260	23.240	-1.508	1.340	0.000	0.000	1.274	0.071	24.305	2.056	1.236	0.000	0.000	0.000	0.000
BENDDS_2		166.324	37.824	-2.081	1.362	0.000	0.000	1.592	0.085	11.141	1.182	1.276	0.000	0.000	0.000	0.000
Q526	F	168.563	43.959	0.296	1.371	0.000	0.000	1.709	-0.016	7.616	0.268	1.316	0.000	0.000	0.000	0.000
BENDDS_1		170.803	35.464	2.521	1.380	0.000	0.000	1.523	-0.115	8.454	-0.497	1.362	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL					
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BENDDS_2		174.867		18.398	1.678	1.405	0.000	0.000	1.083	-0.101		14.923	-1.095	1.421	0.000	0.000	0.000	0.000
BENDDS_1		175.226		17.218	1.604	1.408	0.000	0.000	1.046	-0.101		15.729	-1.148	1.424	0.000	0.000	0.000	0.000
BENDDS_2		179.290		7.610	0.761	1.466	0.000	0.000	0.662	-0.088		27.491	-1.746	1.456	0.000	0.000	0.000	0.000
Q525	D	181.530		5.735	-0.021	1.522	0.000	0.000	0.490	-0.056		33.199	-0.088	1.467	0.000	0.000	0.000	0.000
BENDDS_1		183.769		7.815	-0.813	1.578	0.000	0.000	0.404	-0.030		28.196	1.614	1.479	0.000	0.000	0.000	0.000
BENDDS_2		187.833		17.932	-1.677	1.634	0.000	0.000	0.312	-0.016		17.187	1.095	1.508	0.000	0.000	0.000	0.000
BENDDS_1		188.193		19.165	-1.753	1.637	0.000	0.000	0.306	-0.016		16.417	1.049	1.512	0.000	0.000	0.000	0.000
BENDDS_2		192.257		36.923	-2.617	1.661	0.000	0.000	0.270	-0.002		10.001	0.529	1.563	0.000	0.000	0.000	0.000
Q524	F	194.496		45.716	-0.295	1.670	0.000	0.000	0.254	-0.018		9.044	-0.275	1.602	0.000	0.000	0.000	0.000
BENDDS_1		196.736		39.276	2.177	1.678	0.000	0.000	0.194	-0.032		12.759	-1.233	1.636	0.000	0.000	0.000	0.000
BENDDS_2		200.800		23.993	1.583	1.699	0.000	0.000	0.093	-0.018		26.043	-2.035	1.672	0.000	0.000	0.000	0.000
BENDDS_1		201.159		22.874	1.531	1.702	0.000	0.000	0.086	-0.018		27.532	-2.106	1.674	0.000	0.000	0.000	0.000
BENDDS_2		205.223		12.845	0.937	1.740	0.000	0.000	0.042	-0.004		47.904	-2.906	1.692	0.000	0.000	0.000	0.000
Q523	D	207.463		10.269	0.033	1.772	0.000	0.000	0.035	-0.002		57.000	0.066	1.699	0.000	0.000	0.000	0.000
Q522	F	224.751		55.907	0.019	1.900	0.000	0.000	0.028	-0.002		9.929	-0.025	1.828	0.000	0.000	0.000	0.000
MI52		233.396		24.945	1.418	1.936	0.000	0.000	0.005	-0.003		26.587	-1.536	1.919	0.000	0.000	0.000	0.000
Q521	D	242.040		9.893	-0.034	2.031	0.000	0.000	-0.019	-0.003		59.897	-0.068	1.953	0.000	0.000	0.000	0.000
Q520	F	259.329		59.859	-0.017	2.157	0.000	0.000	-0.091	0.000		11.376	0.020	2.069	0.000	0.000	0.000	0.000
BENDDS_1		261.568		49.884	3.156	2.163	0.000	0.000	-0.084	0.005		13.890	-0.935	2.098	0.000	0.000	0.000	0.000
BENDDS_2		265.632		27.860	2.263	2.181	0.000	0.000	-0.036	0.019		23.719	-1.483	2.134	0.000	0.000	0.000	0.000
BENDDS_1		265.992		26.262	2.184	2.183	0.000	0.000	-0.029	0.019		24.802	-1.531	2.136	0.000	0.000	0.000	0.000
BENDDS_2		270.056		12.139	1.291	2.219	0.000	0.000	0.076	0.033		39.470	-2.078	2.157	0.000	0.000	0.000	0.000
Q519	D	272.295		8.190	0.344	2.256	0.000	0.000	0.154	0.040		45.506	0.348	2.165	0.000	0.000	0.000	0.000
BENDDS_1		274.534		8.705	-0.417	2.300	0.000	0.000	0.260	0.051		36.695	2.598	2.174	0.000	0.000	0.000	0.000
BENDDS_2		278.599		14.322	-0.965	2.359	0.000	0.000	0.495	0.065		19.061	1.741	2.198	0.000	0.000	0.000	0.000
BENDDS_1		278.958		15.033	-1.014	2.363	0.000	0.000	0.519	0.065		17.838	1.665	2.201	0.000	0.000	0.000	0.000
BENDDS_2		283.022		25.499	-1.562	2.396	0.000	0.000	0.810	0.079		7.797	0.806	2.257	0.000	0.000	0.000	0.000
Q518	F	285.261		30.489	0.002	2.409	0.000	0.000	0.947	0.024		5.755	0.008	2.313	0.000	0.000	0.000	0.000
BENDDS_1		287.501		25.482	1.565	2.421	0.000	0.000	0.916	-0.032		7.720	-0.786	2.369	0.000	0.000	0.000	0.000
BENDDS_2		291.565		14.998	1.015	2.455	0.000	0.000	0.813	-0.019		17.568	-1.637	2.426	0.000	0.000	0.000	0.000
BENDDS_1		291.924		14.286	0.966	2.459	0.000	0.000	0.806	-0.019		18.772	-1.712	2.429	0.000	0.000	0.000	0.000
BENDDS_2		295.988		8.668	0.416	2.518	0.000	0.000	0.759	-0.005		36.144	-2.562	2.454	0.000	0.000	0.000	0.000
Q517	D	298.228		8.157	-0.344	2.562	0.000	0.000	0.781	0.040		44.840	-0.347	2.462	0.000	0.000	0.000	0.000
BENDDS_1		300.467		12.103	-1.291	2.599	0.000	0.000	0.942	0.088		38.914	2.042	2.471	0.000	0.000	0.000	0.000
BENDDS_2		304.531		26.229	-2.186	2.636	0.000	0.000	1.327	0.102		24.503	1.503	2.492	0.000	0.000	0.000	0.000
BENDDS_1		304.891		27.829	-2.265	2.638	0.000	0.000	1.363	0.102		23.439	1.456	2.494	0.000	0.000	0.000	0.000
BENDDS_2		308.955		49.873	-3.160	2.655	0.000	0.000	1.805	0.116		13.802	0.915	2.530	0.000	0.000	0.000	0.000
Q516	F	311.194		59.866	0.013	2.662	0.000	0.000	1.978	-0.001		11.366	-0.035	2.560	0.000	0.000	0.000	0.000
BEND_1		313.563		50.875	2.329	2.668	0.000	0.000	1.822	-0.085		13.939	-0.792	2.590	0.000	0.000	0.000	0.000
BEND_2		319.659		27.175	1.559	2.695	0.000	0.000	1.366	-0.064		27.921	-1.501	2.640	0.000	0.000	0.000	0.000
BEND_1		320.018		26.071	1.514	2.697	0.000	0.000	1.343	-0.064		29.015	-1.543	2.642	0.000	0.000	0.000	0.000
BEND_2		326.114		12.307	0.744	2.752	0.000	0.000	1.015	-0.043		52.145	-2.250	2.667	0.000	0.000	0.000	0.000
SD		327.038		11.040	0.628	2.765	0.000	0.000	0.975	-0.043		56.400	-2.358	2.670	0.000	0.000	0.000	0.000
Q515	D	328.483		9.937	0.035	2.787	0.000	0.000	0.934	-0.004		60.725	0.070	2.674	0.000	0.000	0.000	0.000
BEND_1		330.851		11.948	-0.661	2.822	0.000	0.000	0.998	0.036		51.540	2.363	2.681	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_2		336.947		24.473	-1.394	2.880	0.000	0.000	1.280	0.057		27.459	1.586	2.707	0.000	0.000	0.000	0.000
BEND_1		337.307		25.491	-1.437	2.883	0.000	0.000	1.300	0.057		26.335	1.540	2.709	0.000	0.000	0.000	0.000
BEND_2		343.403		47.479	-2.170	2.911	0.000	0.000	1.710	0.078		12.308	0.760	2.764	0.000	0.000	0.000	0.000
SF		344.326		51.590	-2.281	2.914	0.000	0.000	1.781	0.078		11.013	0.642	2.776	0.000	0.000	0.000	0.000
Q514	F	345.771		55.869	-0.014	2.918	0.000	0.000	1.852	-0.002		9.881	0.040	2.799	0.000	0.000	0.000	0.000
BEND_1		348.140		47.603	2.147	2.925	0.000	0.000	1.703	-0.081		11.895	-0.664	2.834	0.000	0.000	0.000	0.000
BEND_2		354.236		25.805	1.429	2.953	0.000	0.000	1.275	-0.060		24.490	-1.401	2.892	0.000	0.000	0.000	0.000
BEND_1		354.595		24.793	1.386	2.955	0.000	0.000	1.253	-0.060		25.513	-1.445	2.895	0.000	0.000	0.000	0.000
BEND_2		360.691		12.270	0.668	3.012	0.000	0.000	0.953	-0.039		47.609	-2.179	2.923	0.000	0.000	0.000	0.000
SD		361.615		11.137	0.559	3.025	0.000	0.000	0.917	-0.039		51.737	-2.291	2.926	0.000	0.000	0.000	0.000
Q513	D	363.060		10.226	-0.034	3.046	0.000	0.000	0.881	-0.001		56.091	-0.068	2.930	0.000	0.000	0.000	0.000
BEND_1		365.428		12.622	-0.750	3.080	0.000	0.000	0.946	0.036		48.192	2.070	2.937	0.000	0.000	0.000	0.000
BEND_2		371.524		26.357	-1.504	3.135	0.000	0.000	1.228	0.057		27.012	1.403	2.964	0.000	0.000	0.000	0.000
BEND_1		371.883		27.453	-1.548	3.137	0.000	0.000	1.248	0.057		26.018	1.364	2.966	0.000	0.000	0.000	0.000
BEND_2		377.979		50.926	-2.302	3.163	0.000	0.000	1.658	0.078		13.467	0.695	3.019	0.000	0.000	0.000	0.000
SF		378.903		55.284	-2.417	3.166	0.000	0.000	1.729	0.078		12.278	0.593	3.030	0.000	0.000	0.000	0.000
Q512	F	380.348		59.782	0.016	3.170	0.000	0.000	1.800	0.001		11.312	-0.044	3.050	0.000	0.000	0.000	0.000
BEND_1		382.716		50.788	2.328	3.176	0.000	0.000	1.661	-0.076		13.925	-0.801	3.081	0.000	0.000	0.000	0.000
BEND_2		388.812		27.101	1.558	3.203	0.000	0.000	1.259	-0.055		28.065	-1.518	3.131	0.000	0.000	0.000	0.000
BEND_1		389.172		25.998	1.512	3.205	0.000	0.000	1.240	-0.055		29.171	-1.560	3.133	0.000	0.000	0.000	0.000
BEND_2		395.268		12.260	0.742	3.260	0.000	0.000	0.965	-0.035		52.552	-2.274	3.158	0.000	0.000	0.000	0.000
SD		396.191		10.998	0.625	3.273	0.000	0.000	0.933	-0.035		56.853	-2.383	3.160	0.000	0.000	0.000	0.000
Q511	D	397.636		9.902	0.033	3.295	0.000	0.000	0.904	0.004		61.231	0.065	3.164	0.000	0.000	0.000	0.000
BEND_1		400.005		11.918	-0.662	3.331	0.000	0.000	0.983	0.042		51.994	2.379	3.171	0.000	0.000	0.000	0.000
BEND_2		406.101		24.473	-1.398	3.389	0.000	0.000	1.304	0.063		27.734	1.600	3.196	0.000	0.000	0.000	0.000
BEND_1		406.460		25.493	-1.441	3.391	0.000	0.000	1.327	0.063		26.601	1.554	3.199	0.000	0.000	0.000	0.000
BEND_2		412.556		47.545	-2.177	3.419	0.000	0.000	1.775	0.084		12.419	0.772	3.253	0.000	0.000	0.000	0.000
SF		413.480		51.669	-2.288	3.422	0.000	0.000	1.852	0.084		11.103	0.653	3.266	0.000	0.000	0.000	0.000
Q510	F	414.925		55.964	-0.018	3.426	0.000	0.000	1.930	0.002		9.941	0.048	3.288	0.000	0.000	0.000	0.000
BEND_1		417.293		47.698	2.148	3.433	0.000	0.000	1.782	-0.081		11.918	-0.655	3.323	0.000	0.000	0.000	0.000
BEND_2		423.389		25.882	1.431	3.461	0.000	0.000	1.352	-0.060		24.360	-1.385	3.381	0.000	0.000	0.000	0.000
BEND_1		423.749		24.869	1.388	3.463	0.000	0.000	1.330	-0.060		25.372	-1.428	3.384	0.000	0.000	0.000	0.000
BEND_2		429.845		12.317	0.671	3.520	0.000	0.000	1.027	-0.039		47.222	-2.155	3.412	0.000	0.000	0.000	0.000
SD		430.768		11.178	0.562	3.533	0.000	0.000	0.991	-0.039		51.305	-2.266	3.415	0.000	0.000	0.000	0.000
Q509	D	432.213		10.260	-0.032	3.554	0.000	0.000	0.956	0.001		55.606	-0.062	3.419	0.000	0.000	0.000	0.000
BEND_1		434.582		12.650	-0.748	3.588	0.000	0.000	1.033	0.042		47.754	2.056	3.426	0.000	0.000	0.000	0.000
BEND_2		440.678		26.352	-1.500	3.642	0.000	0.000	1.352	0.063		26.740	1.390	3.454	0.000	0.000	0.000	0.000
BEND_1		441.037		27.446	-1.544	3.645	0.000	0.000	1.375	0.063		25.755	1.351	3.456	0.000	0.000	0.000	0.000
BEND_2		447.133		50.851	-2.296	3.671	0.000	0.000	1.821	0.084		13.352	0.683	3.509	0.000	0.000	0.000	0.000
SF		448.057		55.196	-2.409	3.673	0.000	0.000	1.898	0.084		12.184	0.582	3.521	0.000	0.000	0.000	0.000
Q508	F	449.502		59.676	0.019	3.677	0.000	0.000	1.974	-0.001		11.247	-0.052	3.541	0.000	0.000	0.000	0.000
BEND_1		451.870		50.684	2.327	3.684	0.000	0.000	1.817	-0.085		13.894	-0.809	3.571	0.000	0.000	0.000	0.000
BEND_2		457.966		27.021	1.555	3.711	0.000	0.000	1.362	-0.064		28.179	-1.534	3.621	0.000	0.000	0.000	0.000
BEND_1		458.326		25.919	1.510	3.713	0.000	0.000	1.339	-0.064		29.296	-1.576	3.623	0.000	0.000	0.000	0.000
BEND_2		464.422		12.214	0.739	3.768	0.000	0.000	1.011	-0.043		52.917	-2.298	3.648	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
SD		465.345		10.957	0.622	3.781	0.000	0.000	0.971	-0.043		57.263	-2.407	3.651	0.000	0.000	0.000	0.000
Q507	D	466.790		9.869	0.031	3.803	0.000	0.000	0.930	-0.004		61.693	0.058	3.655	0.000	0.000	0.000	0.000
BEND_1		469.159		11.891	-0.664	3.839	0.000	0.000	0.993	0.036		52.415	2.392	3.661	0.000	0.000	0.000	0.000
BEND_2		475.255		24.482	-1.402	3.897	0.000	0.000	1.274	0.056		28.002	1.612	3.686	0.000	0.000	0.000	0.000
BEND_1		475.614		25.505	-1.446	3.900	0.000	0.000	1.294	0.056		26.860	1.566	3.689	0.000	0.000	0.000	0.000
BEND_2		481.710		47.629	-2.184	3.928	0.000	0.000	1.701	0.077		12.538	0.783	3.742	0.000	0.000	0.000	0.000
SF		482.633		51.766	-2.296	3.930	0.000	0.000	1.773	0.077		11.201	0.664	3.755	0.000	0.000	0.000	0.000
Q506	F	484.078		56.079	-0.021	3.935	0.000	0.000	1.843	-0.001		10.011	0.056	3.777	0.000	0.000	0.000	0.000
BEND_1		486.447		47.809	2.150	3.942	0.000	0.000	1.695	-0.080		11.957	-0.648	3.812	0.000	0.000	0.000	0.000
BEND_2		492.543		25.965	1.433	3.970	0.000	0.000	1.270	-0.059		24.262	-1.370	3.870	0.000	0.000	0.000	0.000
BEND_1		492.902		24.950	1.391	3.972	0.000	0.000	1.248	-0.059		25.262	-1.413	3.873	0.000	0.000	0.000	0.000
BEND_2		498.998		12.363	0.674	4.028	0.000	0.000	0.950	-0.038		46.880	-2.133	3.901	0.000	0.000	0.000	0.000
SD		499.922		11.219	0.565	4.041	0.000	0.000	0.915	-0.038		50.920	-2.242	3.904	0.000	0.000	0.000	0.000
Q505	D	501.367		10.292	-0.030	4.062	0.000	0.000	0.879	-0.001		55.169	-0.055	3.908	0.000	0.000	0.000	0.000
BEND_1		503.735		12.675	-0.746	4.096	0.000	0.000	0.945	0.036		47.353	2.044	3.916	0.000	0.000	0.000	0.000
BEND_2		509.831		26.338	-1.495	4.150	0.000	0.000	1.229	0.057		26.477	1.379	3.943	0.000	0.000	0.000	0.000
BEND_1		510.191		27.429	-1.539	4.152	0.000	0.000	1.250	0.057		25.500	1.340	3.945	0.000	0.000	0.000	0.000
BEND_2		516.287		50.759	-2.288	4.179	0.000	0.000	1.661	0.078		13.230	0.672	3.999	0.000	0.000	0.000	0.000
SF		517.210		55.090	-2.402	4.181	0.000	0.000	1.733	0.078		12.081	0.571	4.011	0.000	0.000	0.000	0.000
Q504	F	518.655		59.552	0.023	4.185	0.000	0.000	1.805	0.001		11.171	-0.059	4.031	0.000	0.000	0.000	0.000
BEND_1		521.024		50.566	2.324	4.192	0.000	0.000	1.665	-0.076		13.847	-0.816	4.062	0.000	0.000	0.000	0.000
BEND_2		527.120		26.935	1.552	4.219	0.000	0.000	1.264	-0.055		28.261	-1.548	4.112	0.000	0.000	0.000	0.000
BEND_1		527.479		25.835	1.507	4.221	0.000	0.000	1.244	-0.055		29.389	-1.591	4.114	0.000	0.000	0.000	0.000
BEND_2		533.575		12.168	0.735	4.277	0.000	0.000	0.969	-0.035		53.234	-2.320	4.138	0.000	0.000	0.000	0.000
SD		534.499		10.918	0.618	4.289	0.000	0.000	0.937	-0.035		57.621	-2.430	4.141	0.000	0.000	0.000	0.000
Q503	D	535.944		9.838	0.029	4.312	0.000	0.000	0.908	0.004		62.103	0.051	4.145	0.000	0.000	0.000	0.000
BEND_1		538.312		11.868	-0.666	4.348	0.000	0.000	0.988	0.042		52.795	2.402	4.151	0.000	0.000	0.000	0.000
BEND_2		544.408		24.501	-1.407	4.406	0.000	0.000	1.311	0.063		28.259	1.622	4.177	0.000	0.000	0.000	0.000
BEND_1		544.768		25.528	-1.450	4.408	0.000	0.000	1.333	0.063		27.109	1.576	4.179	0.000	0.000	0.000	0.000
BEND_2		550.864		47.729	-2.192	4.436	0.000	0.000	1.783	0.084		12.663	0.793	4.232	0.000	0.000	0.000	0.000
SF		551.787		51.881	-2.304	4.439	0.000	0.000	1.861	0.084		11.307	0.675	4.244	0.000	0.000	0.000	0.000
Q502	F	553.232		56.213	-0.024	4.443	0.000	0.000	1.938	0.001		10.092	0.063	4.266	0.000	0.000	0.000	0.000
BEND_1		555.601		47.935	2.153	4.450	0.000	0.000	1.790	-0.081		12.011	-0.642	4.301	0.000	0.000	0.000	0.000
BEND_2		561.697		26.054	1.436	4.478	0.000	0.000	1.357	-0.061		24.196	-1.357	4.359	0.000	0.000	0.000	0.000
BEND_1		562.056		25.037	1.394	4.480	0.000	0.000	1.335	-0.061		25.186	-1.399	4.362	0.000	0.000	0.000	0.000
BEND_2		568.152		12.408	0.677	4.536	0.000	0.000	1.029	-0.040		46.590	-2.111	4.390	0.000	0.000	0.000	0.000
SD		569.076		11.257	0.569	4.549	0.000	0.000	0.993	-0.040		50.589	-2.220	4.393	0.000	0.000	0.000	0.000
Q501	D	570.521		10.322	-0.028	4.570	0.000	0.000	0.957	0.001		54.788	-0.047	4.398	0.000	0.000	0.000	0.000
MI50		570.521		10.322	-0.028	4.570	0.000	0.000	0.957	0.001		54.788	-0.047	4.398	0.000	0.000	0.000	0.000
BEND_1		572.889		12.695	-0.744	4.604	0.000	0.000	1.034	0.042		46.994	2.036	4.405	0.000	0.000	0.000	0.000
BEND_2		578.985		26.314	-1.490	4.658	0.000	0.000	1.351	0.062		26.228	1.370	4.433	0.000	0.000	0.000	0.000
BEND_1		579.344		27.401	-1.534	4.660	0.000	0.000	1.373	0.062		25.257	1.331	4.435	0.000	0.000	0.000	0.000
BEND_2		585.440		50.651	-2.280	4.686	0.000	0.000	1.817	0.083		13.102	0.663	4.489	0.000	0.000	0.000	0.000
SF		586.364		54.967	-2.393	4.689	0.000	0.000	1.894	0.083		11.972	0.561	4.501	0.000	0.000	0.000	0.000
Q430	F	587.809		59.410	0.025	4.693	0.000	0.000	1.969	-0.001		11.086	-0.066	4.521	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE element name	quad type	dist [m]	I I	HORIZONTAL betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	VERTICAL betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_1		590.177		50.433	2.321	4.700	0.000	0.000	1.813	-0.085		13.785	-0.822	4.552	0.000	0.000	0.000	0.000
BEND_2		596.273		26.844	1.549	4.727	0.000	0.000	1.358	-0.064		28.310	-1.561	4.602	0.000	0.000	0.000	0.000
BEND_1		596.633		25.747	1.503	4.729	0.000	0.000	1.335	-0.064		29.448	-1.604	4.604	0.000	0.000	0.000	0.000
BEND_2		602.729		12.123	0.732	4.785	0.000	0.000	1.007	-0.043		53.498	-2.340	4.629	0.000	0.000	0.000	0.000
SD		603.652		10.880	0.615	4.798	0.000	0.000	0.967	-0.043		57.924	-2.452	4.632	0.000	0.000	0.000	0.000
Q429	D	605.097		9.810	0.026	4.820	0.000	0.000	0.926	-0.004		62.455	0.043	4.635	0.000	0.000	0.000	0.000
BEND_1		607.466		11.850	-0.668	4.856	0.000	0.000	0.989	0.035		53.130	2.409	4.642	0.000	0.000	0.000	0.000
BEND_2		613.562		24.529	-1.412	4.914	0.000	0.000	1.267	0.056		28.500	1.630	4.667	0.000	0.000	0.000	0.000
BEND_1		613.921		25.560	-1.456	4.916	0.000	0.000	1.288	0.056		27.344	1.584	4.669	0.000	0.000	0.000	0.000
BEND_2		620.017		47.845	-2.200	4.944	0.000	0.000	1.693	0.077		12.792	0.803	4.722	0.000	0.000	0.000	0.000
SF		620.941		52.012	-2.313	4.947	0.000	0.000	1.765	0.077		11.419	0.684	4.734	0.000	0.000	0.000	0.000
Q428	F	622.386		56.363	-0.027	4.951	0.000	0.000	1.834	-0.001		10.181	0.068	4.756	0.000	0.000	0.000	0.000
BEND_1		624.754		48.075	2.157	4.959	0.000	0.000	1.687	-0.080		12.080	-0.637	4.790	0.000	0.000	0.000	0.000
BEND_2		630.850		26.147	1.440	4.986	0.000	0.000	1.265	-0.059		24.164	-1.345	4.848	0.000	0.000	0.000	0.000
BEND_1		631.210		25.127	1.398	4.988	0.000	0.000	1.244	-0.059		25.145	-1.387	4.851	0.000	0.000	0.000	0.000
BEND_2		637.306		12.452	0.681	5.044	0.000	0.000	0.948	-0.038		46.354	-2.092	4.879	0.000	0.000	0.000	0.000
SD		638.229		11.294	0.573	5.057	0.000	0.000	0.913	-0.038		50.317	-2.199	4.882	0.000	0.000	0.000	0.000
Q427	D	639.674		10.349	-0.025	5.078	0.000	0.000	0.878	-0.001		54.468	-0.038	4.887	0.000	0.000	0.000	0.000
BEND_1		642.043		12.712	-0.741	5.112	0.000	0.000	0.945	0.037		46.685	2.030	4.894	0.000	0.000	0.000	0.000
BEND_2		648.139		26.281	-1.485	5.166	0.000	0.000	1.232	0.057		25.996	1.363	4.922	0.000	0.000	0.000	0.000
BEND_1		648.498		27.364	-1.528	5.168	0.000	0.000	1.252	0.057		25.030	1.324	4.924	0.000	0.000	0.000	0.000
BEND_2		654.594		50.528	-2.272	5.194	0.000	0.000	1.666	0.078		12.972	0.654	4.979	0.000	0.000	0.000	0.000
SF		655.518		54.828	-2.384	5.197	0.000	0.000	1.738	0.078		11.857	0.552	4.991	0.000	0.000	0.000	0.000
Q426	F	656.963		59.252	0.028	5.201	0.000	0.000	1.810	0.001		10.993	-0.071	5.012	0.000	0.000	0.000	0.000
BEND_1		659.331		50.287	2.317	5.208	0.000	0.000	1.670	-0.076		13.709	-0.826	5.043	0.000	0.000	0.000	0.000
BEND_2		665.427		26.749	1.545	5.235	0.000	0.000	1.268	-0.056		28.326	-1.572	5.093	0.000	0.000	0.000	0.000
BEND_1		665.787		25.655	1.499	5.237	0.000	0.000	1.248	-0.056		29.471	-1.616	5.095	0.000	0.000	0.000	0.000
BEND_2		671.883		12.080	0.728	5.293	0.000	0.000	0.973	-0.035		53.704	-2.359	5.119	0.000	0.000	0.000	0.000
SD		672.806		10.844	0.611	5.306	0.000	0.000	0.941	-0.035		58.165	-2.472	5.122	0.000	0.000	0.000	0.000
Q425	D	674.251		9.784	0.024	5.329	0.000	0.000	0.912	0.004		62.742	0.034	5.126	0.000	0.000	0.000	0.000
BEND_1		676.620		11.836	-0.671	5.364	0.000	0.000	0.992	0.043		53.412	2.413	5.132	0.000	0.000	0.000	0.000
BEND_2		682.716		24.567	-1.418	5.423	0.000	0.000	1.317	0.064		28.721	1.636	5.157	0.000	0.000	0.000	0.000
BEND_1		683.075		25.602	-1.462	5.425	0.000	0.000	1.339	0.064		27.561	1.590	5.159	0.000	0.000	0.000	0.000
BEND_2		689.171		47.975	-2.209	5.453	0.000	0.000	1.791	0.084		12.923	0.810	5.211	0.000	0.000	0.000	0.000
SF		690.094		52.158	-2.322	5.456	0.000	0.000	1.869	0.084		11.535	0.692	5.224	0.000	0.000	0.000	0.000
Q424	F	691.539		56.529	-0.029	5.460	0.000	0.000	1.947	0.001		10.277	0.073	5.245	0.000	0.000	0.000	0.000
BEND_1		693.908		48.226	2.162	5.467	0.000	0.000	1.797	-0.082		12.163	-0.634	5.280	0.000	0.000	0.000	0.000
BEND_2		700.004		26.243	1.445	5.494	0.000	0.000	1.361	-0.061		24.165	-1.335	5.337	0.000	0.000	0.000	0.000
BEND_1		700.363		25.220	1.402	5.497	0.000	0.000	1.340	-0.061		25.140	-1.376	5.340	0.000	0.000	0.000	0.000
BEND_2		706.459		12.494	0.685	5.552	0.000	0.000	1.031	-0.040		46.179	-2.075	5.368	0.000	0.000	0.000	0.000
SD		707.383		11.329	0.577	5.565	0.000	0.000	0.994	-0.040		50.108	-2.181	5.371	0.000	0.000	0.000	0.000
Q423	D	708.828		10.373	-0.022	5.586	0.000	0.000	0.958	0.000		54.215	-0.029	5.376	0.000	0.000	0.000	0.000
BEND_1		711.196		12.723	-0.738	5.620	0.000	0.000	1.034	0.041		46.430	2.028	5.383	0.000	0.000	0.000	0.000
BEND_2		717.292		26.239	-1.479	5.674	0.000	0.000	1.348	0.062		25.786	1.358	5.411	0.000	0.000	0.000	0.000
BEND_1		717.652		27.318	-1.522	5.676	0.000	0.000	1.370	0.062		24.824	1.319	5.414	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE element name	quad type	dist [m]	HORIZONTAL betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	VERTICAL betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_2		723.748	50.391	-2.263	5.702	0.000	0.000	1.812	0.083	12.840	0.647	5.469	0.000	0.000	0.000	0.000
SF		724.671	54.674	-2.375	5.705	0.000	0.000	1.888	0.083	11.740	0.545	5.481	0.000	0.000	0.000	0.000
Q422	F	726.116	59.078	0.030	5.709	0.000	0.000	1.964	-0.001	10.894	-0.075	5.502	0.000	0.000	0.000	0.000
BEND_1		728.485	50.130	2.312	5.716	0.000	0.000	1.807	-0.085	13.620	-0.828	5.533	0.000	0.000	0.000	0.000
BEND_2		734.581	26.651	1.540	5.743	0.000	0.000	1.353	-0.064	28.307	-1.581	5.584	0.000	0.000	0.000	0.000
BEND_1		734.940	25.561	1.495	5.745	0.000	0.000	1.330	-0.064	29.459	-1.625	5.586	0.000	0.000	0.000	0.000
BEND_2		741.036	12.039	0.723	5.801	0.000	0.000	1.003	-0.043	53.849	-2.375	5.610	0.000	0.000	0.000	0.000
SD		741.960	10.811	0.607	5.814	0.000	0.000	0.963	-0.043	58.340	-2.489	5.613	0.000	0.000	0.000	0.000
Q421	D	743.405	9.761	0.020	5.837	0.000	0.000	0.922	-0.004	62.960	0.024	5.616	0.000	0.000	0.000	0.000
BEND_1		745.773	11.827	-0.674	5.873	0.000	0.000	0.984	0.035	53.639	2.414	5.623	0.000	0.000	0.000	0.000
BEND_2		751.869	24.614	-1.424	5.931	0.000	0.000	1.261	0.056	28.919	1.640	5.647	0.000	0.000	0.000	0.000
BEND_1		752.229	25.653	-1.468	5.933	0.000	0.000	1.282	0.056	27.757	1.594	5.649	0.000	0.000	0.000	0.000
BEND_2		758.325	48.118	-2.218	5.961	0.000	0.000	1.686	0.077	13.054	0.817	5.701	0.000	0.000	0.000	0.000
SF		759.248	52.318	-2.331	5.964	0.000	0.000	1.757	0.077	11.654	0.699	5.713	0.000	0.000	0.000	0.000
Q420	F	760.693	56.709	-0.031	5.968	0.000	0.000	1.826	-0.001	10.379	0.077	5.735	0.000	0.000	0.000	0.000
BEND_1		763.062	48.388	2.167	5.975	0.000	0.000	1.680	-0.079	12.259	-0.632	5.769	0.000	0.000	0.000	0.000
BEND_2		769.158	26.342	1.450	6.003	0.000	0.000	1.260	-0.058	24.201	-1.327	5.826	0.000	0.000	0.000	0.000
BEND_1		769.517	25.316	1.407	6.005	0.000	0.000	1.239	-0.058	25.170	-1.368	5.829	0.000	0.000	0.000	0.000
BEND_2		775.613	12.534	0.690	6.060	0.000	0.000	0.947	-0.038	46.066	-2.060	5.857	0.000	0.000	0.000	0.000
SD		776.537	11.361	0.581	6.073	0.000	0.000	0.912	-0.038	49.967	-2.165	5.860	0.000	0.000	0.000	0.000
Q419	D	777.982	10.394	-0.019	6.094	0.000	0.000	0.878	0.000	54.032	-0.019	5.865	0.000	0.000	0.000	0.000
BEND_1		780.350	12.730	-0.735	6.128	0.000	0.000	0.946	0.037	46.233	2.028	5.872	0.000	0.000	0.000	0.000
BEND_2		786.446	26.188	-1.473	6.182	0.000	0.000	1.234	0.058	25.601	1.356	5.901	0.000	0.000	0.000	0.000
BEND_1		786.805	27.262	-1.516	6.184	0.000	0.000	1.255	0.058	24.641	1.316	5.903	0.000	0.000	0.000	0.000
BEND_2		792.901	50.242	-2.254	6.210	0.000	0.000	1.671	0.079	12.710	0.641	5.959	0.000	0.000	0.000	0.000
SF		793.825	54.508	-2.366	6.213	0.000	0.000	1.744	0.079	11.621	0.538	5.971	0.000	0.000	0.000	0.000
Q418	F	795.270	58.892	0.032	6.217	0.000	0.000	1.816	0.001	10.790	-0.078	5.992	0.000	0.000	0.000	0.000
BEND_1		797.638	49.964	2.306	6.224	0.000	0.000	1.676	-0.077	13.519	-0.829	6.024	0.000	0.000	0.000	0.000
BEND_2		803.734	26.552	1.535	6.251	0.000	0.000	1.274	-0.056	28.254	-1.588	6.074	0.000	0.000	0.000	0.000
BEND_1		804.094	25.465	1.490	6.253	0.000	0.000	1.254	-0.056	29.411	-1.633	6.076	0.000	0.000	0.000	0.000
BEND_2		810.190	12.001	0.719	6.310	0.000	0.000	0.978	-0.035	53.930	-2.389	6.101	0.000	0.000	0.000	0.000
SD		811.113	10.780	0.602	6.323	0.000	0.000	0.946	-0.035	58.448	-2.503	6.103	0.000	0.000	0.000	0.000
Q417	D	812.558	9.742	0.017	6.345	0.000	0.000	0.916	0.004	63.106	0.014	6.107	0.000	0.000	0.000	0.000
BEND_1		814.927	11.822	-0.678	6.381	0.000	0.000	0.997	0.043	53.805	2.412	6.113	0.000	0.000	0.000	0.000
BEND_2		821.023	24.669	-1.430	6.439	0.000	0.000	1.322	0.064	29.091	1.641	6.138	0.000	0.000	0.000	0.000
BEND_1		821.382	25.713	-1.474	6.442	0.000	0.000	1.345	0.064	27.927	1.596	6.140	0.000	0.000	0.000	0.000
BEND_2		827.478	48.272	-2.227	6.469	0.000	0.000	1.798	0.085	13.183	0.822	6.191	0.000	0.000	0.000	0.000
SF		828.402	52.490	-2.341	6.472	0.000	0.000	1.876	0.085	11.772	0.705	6.203	0.000	0.000	0.000	0.000
Q416	F	829.847	56.901	-0.033	6.476	0.000	0.000	1.954	0.001	10.484	0.079	6.224	0.000	0.000	0.000	0.000
BEND_1		832.215	48.558	2.173	6.484	0.000	0.000	1.804	-0.082	12.365	-0.632	6.258	0.000	0.000	0.000	0.000
BEND_2		838.311	26.442	1.455	6.511	0.000	0.000	1.366	-0.061	24.271	-1.321	6.315	0.000	0.000	0.000	0.000
BEND_1		838.671	25.412	1.413	6.513	0.000	0.000	1.343	-0.061	25.235	-1.361	6.318	0.000	0.000	0.000	0.000
BEND_2		844.767	12.571	0.694	6.568	0.000	0.000	1.032	-0.041	46.017	-2.047	6.346	0.000	0.000	0.000	0.000
SD		845.690	11.390	0.585	6.581	0.000	0.000	0.995	-0.041	49.894	-2.151	6.349	0.000	0.000	0.000	0.000
Q415	D	847.135	10.412	-0.016	6.602	0.000	0.000	0.958	0.000	53.924	-0.009	6.354	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_1		849.504		12.732	-0.731	6.636	0.000	0.000	1.033	0.041		46.098	2.032	6.361	0.000	0.000	0.000	0.000
BEND_2		855.600		26.129	-1.466	6.690	0.000	0.000	1.345	0.062		25.444	1.355	6.390	0.000	0.000	0.000	0.000
BEND_1		855.959		27.198	-1.510	6.692	0.000	0.000	1.367	0.062		24.484	1.315	6.392	0.000	0.000	0.000	0.000
BEND_2		862.055		50.082	-2.245	6.718	0.000	0.000	1.806	0.082		12.584	0.636	6.448	0.000	0.000	0.000	0.000
SF		862.979		54.331	-2.356	6.721	0.000	0.000	1.882	0.082		11.504	0.533	6.461	0.000	0.000	0.000	0.000
Q414	F	864.424		58.695	0.034	6.725	0.000	0.000	1.957	-0.001		10.684	-0.079	6.482	0.000	0.000	0.000	0.000
BEND_1		866.792		49.789	2.299	6.732	0.000	0.000	1.801	-0.085		13.408	-0.828	6.514	0.000	0.000	0.000	0.000
BEND_2		872.888		26.451	1.530	6.759	0.000	0.000	1.348	-0.064		28.168	-1.593	6.565	0.000	0.000	0.000	0.000
BEND_1		873.248		25.368	1.484	6.761	0.000	0.000	1.325	-0.064		29.329	-1.638	6.567	0.000	0.000	0.000	0.000
BEND_2		879.344		11.965	0.715	6.818	0.000	0.000	0.999	-0.043		53.946	-2.400	6.591	0.000	0.000	0.000	0.000
SD		880.267		10.753	0.598	6.831	0.000	0.000	0.959	-0.043		58.485	-2.515	6.594	0.000	0.000	0.000	0.000
Q413	D	881.712		9.726	0.014	6.854	0.000	0.000	0.918	-0.004		63.176	0.004	6.597	0.000	0.000	0.000	0.000
BEND_1		884.081		11.822	-0.681	6.890	0.000	0.000	0.980	0.035		53.909	2.407	6.604	0.000	0.000	0.000	0.000
BEND_2		890.177		24.732	-1.436	6.948	0.000	0.000	1.256	0.056		29.233	1.640	6.628	0.000	0.000	0.000	0.000
BEND_1		890.536		25.780	-1.481	6.950	0.000	0.000	1.276	0.056		28.070	1.595	6.630	0.000	0.000	0.000	0.000
BEND_2		896.632		48.437	-2.236	6.978	0.000	0.000	1.679	0.077		13.307	0.826	6.681	0.000	0.000	0.000	0.000
SF		897.555		52.673	-2.350	6.981	0.000	0.000	1.750	0.077		11.889	0.709	6.693	0.000	0.000	0.000	0.000
Q412	F	899.000		57.103	-0.035	6.985	0.000	0.000	1.819	-0.001		10.592	0.080	6.714	0.000	0.000	0.000	0.000
BEND_1		901.369		48.736	2.180	6.992	0.000	0.000	1.674	-0.079		12.480	-0.634	6.748	0.000	0.000	0.000	0.000
BEND_2		907.465		26.543	1.461	7.019	0.000	0.000	1.257	-0.058		24.373	-1.317	6.804	0.000	0.000	0.000	0.000
BEND_1		907.824		25.508	1.418	7.021	0.000	0.000	1.236	-0.058		25.334	-1.357	6.807	0.000	0.000	0.000	0.000
BEND_2		913.920		12.605	0.699	7.076	0.000	0.000	0.946	-0.037		46.033	-2.038	6.835	0.000	0.000	0.000	0.000
SD		914.844		11.416	0.590	7.089	0.000	0.000	0.912	-0.037		49.892	-2.141	6.838	0.000	0.000	0.000	0.000
Q411	D	916.289		10.426	-0.012	7.110	0.000	0.000	0.878	0.000		53.892	0.001	6.843	0.000	0.000	0.000	0.000
BEND_1		918.657		12.730	-0.727	7.143	0.000	0.000	0.946	0.037		46.026	2.039	6.850	0.000	0.000	0.000	0.000
BEND_2		924.753		26.062	-1.460	7.198	0.000	0.000	1.238	0.058		25.317	1.358	6.879	0.000	0.000	0.000	0.000
BEND_1		925.113		27.127	-1.503	7.200	0.000	0.000	1.259	0.058		24.356	1.317	6.881	0.000	0.000	0.000	0.000
BEND_2		931.209		49.913	-2.235	7.226	0.000	0.000	1.677	0.079		12.462	0.633	6.938	0.000	0.000	0.000	0.000
SF		932.132		54.144	-2.346	7.229	0.000	0.000	1.750	0.079		11.388	0.530	6.950	0.000	0.000	0.000	0.000
Q410	F	933.577		58.489	0.035	7.233	0.000	0.000	1.823	0.001		10.576	-0.080	6.971	0.000	0.000	0.000	0.000
BEND_1		935.946		49.609	2.292	7.240	0.000	0.000	1.683	-0.077		13.289	-0.826	7.004	0.000	0.000	0.000	0.000
BEND_2		942.042		26.351	1.524	7.267	0.000	0.000	1.279	-0.056		28.051	-1.595	7.055	0.000	0.000	0.000	0.000
BEND_1		942.401		25.272	1.478	7.269	0.000	0.000	1.259	-0.056		29.214	-1.641	7.057	0.000	0.000	0.000	0.000
BEND_2		948.497		11.933	0.710	7.326	0.000	0.000	0.982	-0.035		53.897	-2.408	7.082	0.000	0.000	0.000	0.000
SD		949.421		10.729	0.594	7.339	0.000	0.000	0.950	-0.035		58.452	-2.524	7.084	0.000	0.000	0.000	0.000
Q409	D	950.866		9.714	0.010	7.362	0.000	0.000	0.920	0.004		63.170	-0.006	7.088	0.000	0.000	0.000	0.000
BEND_1		953.234		11.827	-0.685	7.398	0.000	0.000	1.001	0.043		53.948	2.398	7.094	0.000	0.000	0.000	0.000
BEND_2		959.330		24.802	-1.443	7.456	0.000	0.000	1.328	0.064		29.344	1.637	7.119	0.000	0.000	0.000	0.000
BEND_1		959.690		25.855	-1.488	7.458	0.000	0.000	1.351	0.064		28.183	1.592	7.121	0.000	0.000	0.000	0.000
BEND_2		965.786		48.610	-2.245	7.486	0.000	0.000	1.805	0.085		13.425	0.828	7.172	0.000	0.000	0.000	0.000
SF		966.709		52.863	-2.360	7.489	0.000	0.000	1.883	0.085		12.002	0.712	7.183	0.000	0.000	0.000	0.000
Q408	F	968.154		57.313	-0.036	7.493	0.000	0.000	1.961	0.001		10.699	0.079	7.204	0.000	0.000	0.000	0.000
BENDDS_1		970.394		47.848	3.004	7.500	0.000	0.000	1.790	-0.114		12.821	-0.830	7.235	0.000	0.000	0.000	0.000
BENDDS_2		974.458		26.891	2.153	7.518	0.000	0.000	1.354	-0.100		21.737	-1.364	7.274	0.000	0.000	0.000	0.000
BENDDS_1		974.817		25.371	2.077	7.520	0.000	0.000	1.318	-0.100		22.734	-1.411	7.277	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BENDDS_2		978.881		11.947	1.226	7.557	0.000	0.000	0.940	-0.086		36.371	-1.944	7.299	0.000	0.000	0.000	0.000
Q407	D	981.121		8.239	0.298	7.594	0.000	0.000	0.782	-0.038		42.092	0.283	7.308	0.000	0.000	0.000	0.000
BENDDS_1		983.360		8.969	-0.468	7.637	0.000	0.000	0.764	0.006		34.108	2.369	7.318	0.000	0.000	0.000	0.000
BENDDS_2		987.424		15.015	-1.020	7.694	0.000	0.000	0.817	0.020		18.052	1.582	7.344	0.000	0.000	0.000	0.000
BENDDS_1		987.783		15.766	-1.069	7.698	0.000	0.000	0.825	0.020		16.940	1.512	7.347	0.000	0.000	0.000	0.000
BENDDS_2		991.848		26.698	-1.621	7.730	0.000	0.000	0.935	0.034		7.852	0.724	7.404	0.000	0.000	0.000	0.000
Q406	F	994.087		31.840	0.023	7.742	0.000	0.000	0.969	-0.024		6.116	-0.057	7.458	0.000	0.000	0.000	0.000
BENDDS_1		996.326		26.514	1.656	7.754	0.000	0.000	0.831	-0.080		8.419	-0.869	7.510	0.000	0.000	0.000	0.000
BENDDS_2		1000.390		15.387	1.082	7.786	0.000	0.000	0.535	-0.066		18.921	-1.715	7.562	0.000	0.000	0.000	0.000
BENDDS_1		1000.750		14.628	1.031	7.790	0.000	0.000	0.512	-0.066		20.180	-1.790	7.565	0.000	0.000	0.000	0.000
BENDDS_2		1004.814		8.574	0.458	7.849	0.000	0.000	0.273	-0.052		38.163	-2.635	7.588	0.000	0.000	0.000	0.000
Q405	D	1007.053		7.884	-0.299	7.894	0.000	0.000	0.166	-0.040		46.989	-0.288	7.597	0.000	0.000	0.000	0.000
BENDDS_1		1009.293		11.562	-1.219	7.933	0.000	0.000	0.088	-0.032		40.463	2.203	7.605	0.000	0.000	0.000	0.000
BENDDS_2		1013.357		25.018	-2.092	7.971	0.000	0.000	-0.015	-0.018		24.937	1.616	7.625	0.000	0.000	0.000	0.000
BENDDS_1		1013.716		26.550	-2.170	7.973	0.000	0.000	-0.021	-0.018		23.794	1.564	7.627	0.000	0.000	0.000	0.000
BENDDS_2		1017.780		47.734	-3.043	7.991	0.000	0.000	-0.068	-0.004		13.468	0.976	7.664	0.000	0.000	0.000	0.000
Q404	F	1020.020		57.397	-0.010	7.998	0.000	0.000	-0.075	0.000		10.772	0.034	7.694	0.000	0.000	0.000	0.000
Q403	D	1037.308		10.172	-0.007	8.125	0.000	0.000	-0.023	0.002		56.533	0.015	7.818	0.000	0.000	0.000	0.000
Q402	F	1054.597		58.208	0.011	8.250	0.000	0.000	-0.002	0.001		10.449	-0.033	7.944	0.000	0.000	0.000	0.000
MI40		1054.597		58.208	0.011	8.250	0.000	0.000	-0.002	0.001		10.449	-0.033	7.944	0.000	0.000	0.000	0.000
Q401	D	1071.886		9.956	0.006	8.378	0.000	0.000	0.022	0.002		60.357	-0.018	8.065	0.000	0.000	0.000	0.000
Q400	F	1089.174		57.461	-0.011	8.506	0.000	0.000	0.075	0.000		10.822	0.031	8.183	0.000	0.000	0.000	0.000
BENDDS_1		1091.414		47.872	3.031	8.513	0.000	0.000	0.068	-0.004		13.198	-0.895	8.214	0.000	0.000	0.000	0.000
BENDDS_2		1095.478		26.753	2.166	8.531	0.000	0.000	0.079	0.010		22.723	-1.449	8.251	0.000	0.000	0.000	0.000
BENDDS_1		1095.837		25.223	2.090	8.533	0.000	0.000	0.082	0.010		23.782	-1.498	8.254	0.000	0.000	0.000	0.000
BENDDS_2		1099.901		11.753	1.225	8.571	0.000	0.000	0.149	0.023		38.200	-2.050	8.275	0.000	0.000	0.000	0.000
Q341	D	1102.141		8.051	0.301	8.609	0.000	0.000	0.209	0.034		44.233	0.295	8.284	0.000	0.000	0.000	0.000
BENDDS_1		1104.380		8.749	-0.460	8.653	0.000	0.000	0.306	0.048		35.841	2.492	8.293	0.000	0.000	0.000	0.000
BENDDS_2		1108.444		14.777	-1.023	8.711	0.000	0.000	0.530	0.062		18.902	1.675	8.318	0.000	0.000	0.000	0.000
BENDDS_1		1108.804		15.530	-1.073	8.715	0.000	0.000	0.553	0.062		17.724	1.603	8.321	0.000	0.000	0.000	0.000
BENDDS_2		1112.868		26.537	-1.636	8.747	0.000	0.000	0.833	0.076		8.019	0.785	8.376	0.000	0.000	0.000	0.000
Q340	F	1115.107		31.766	-0.002	8.759	0.000	0.000	0.963	0.020		6.045	-0.008	8.430	0.000	0.000	0.000	0.000
BENDDS_1		1117.347		26.552	1.633	8.771	0.000	0.000	0.922	-0.037		8.099	-0.805	8.483	0.000	0.000	0.000	0.000
BENDDS_2		1121.411		15.560	1.072	8.803	0.000	0.000	0.799	-0.023		18.004	-1.632	8.537	0.000	0.000	0.000	0.000
BENDDS_1		1121.770		14.808	1.022	8.807	0.000	0.000	0.791	-0.023		19.203	-1.705	8.540	0.000	0.000	0.000	0.000
BENDDS_2		1125.834		8.781	0.461	8.865	0.000	0.000	0.725	-0.009		36.415	-2.530	8.565	0.000	0.000	0.000	0.000
Q339	D	1128.074		8.079	-0.301	8.909	0.000	0.000	0.735	0.033		44.926	-0.296	8.574	0.000	0.000	0.000	0.000
BENDDS_1		1130.313		11.784	-1.226	8.947	0.000	0.000	0.876	0.078		38.779	2.087	8.582	0.000	0.000	0.000	0.000
BENDDS_2		1134.377		25.251	-2.088	8.984	0.000	0.000	1.220	0.092		24.094	1.527	8.603	0.000	0.000	0.000	0.000
BENDDS_1		1134.737		26.780	-2.165	8.987	0.000	0.000	1.253	0.092		23.014	1.477	8.606	0.000	0.000	0.000	0.000
BENDDS_2		1138.801		47.881	-3.028	9.005	0.000	0.000	1.654	0.106		13.290	0.916	8.643	0.000	0.000	0.000	0.000
Q338	F	1141.040		57.454	0.015	9.011	0.000	0.000	1.812	-0.001		10.833	-0.015	8.674	0.000	0.000	0.000	0.000
BEND_1		1143.409		48.821	2.234	9.018	0.000	0.000	1.668	-0.078		13.239	-0.753	8.706	0.000	0.000	0.000	0.000
BEND_2		1149.505		26.146	1.486	9.046	0.000	0.000	1.254	-0.057		26.816	-1.473	8.758	0.000	0.000	0.000	0.000
BEND_1		1149.864		25.093	1.442	9.048	0.000	0.000	1.234	-0.057		27.890	-1.516	8.760	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL					
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_2		1155.960		12.074	0.694	9.105	0.000	0.000	0.947	-0.037		50.749	-2.233	8.786	0.000	0.000	0.000	0.000
SD		1156.883		10.897	0.581	9.118	0.000	0.000	0.913	-0.037		54.974	-2.342	8.789	0.000	0.000	0.000	0.000
Q337	D	1158.328		9.921	-0.007	9.140	0.000	0.000	0.881	0.001		59.323	0.023	8.793	0.000	0.000	0.000	0.000
BEND_1		1160.697		12.143	-0.710	9.175	0.000	0.000	0.951	0.038		50.549	2.271	8.800	0.000	0.000	0.000	0.000
BEND_2		1166.793		25.399	-1.465	9.232	0.000	0.000	1.247	0.059		27.375	1.530	8.826	0.000	0.000	0.000	0.000
BEND_1		1167.152		26.468	-1.509	9.234	0.000	0.000	1.269	0.059		26.291	1.486	8.828	0.000	0.000	0.000	0.000
BEND_2		1173.248		49.471	-2.264	9.261	0.000	0.000	1.692	0.080		12.700	0.743	8.882	0.000	0.000	0.000	0.000
SF		1174.172		53.759	-2.379	9.264	0.000	0.000	1.766	0.080		11.432	0.630	8.894	0.000	0.000	0.000	0.000
Q336	F	1175.617		58.220	-0.014	9.268	0.000	0.000	1.840	0.001		10.341	0.017	8.916	0.000	0.000	0.000	0.000
BEND_1		1177.985		49.595	2.241	9.275	0.000	0.000	1.698	-0.077		12.523	-0.702	8.950	0.000	0.000	0.000	0.000
BEND_2		1184.081		26.783	1.501	9.301	0.000	0.000	1.291	-0.056		25.503	-1.427	9.005	0.000	0.000	0.000	0.000
BEND_1		1184.441		25.720	1.457	9.304	0.000	0.000	1.271	-0.056		26.544	-1.470	9.007	0.000	0.000	0.000	0.000
BEND_2		1190.537		12.466	0.717	9.359	0.000	0.000	0.990	-0.036		48.871	-2.192	9.034	0.000	0.000	0.000	0.000
SD		1191.460		11.245	0.605	9.371	0.000	0.000	0.957	-0.036		53.021	-2.302	9.037	0.000	0.000	0.000	0.000
Q335	D	1192.905		10.210	0.007	9.393	0.000	0.000	0.927	0.004		57.344	-0.022	9.041	0.000	0.000	0.000	0.000
BEND_1		1195.274		12.390	-0.699	9.427	0.000	0.000	1.008	0.043		49.062	2.156	9.048	0.000	0.000	0.000	0.000
BEND_2		1201.370		25.380	-1.432	9.483	0.000	0.000	1.334	0.064		27.035	1.456	9.075	0.000	0.000	0.000	0.000
BEND_1		1201.729		26.425	-1.475	9.485	0.000	0.000	1.357	0.064		26.004	1.415	9.077	0.000	0.000	0.000	0.000
BEND_2		1207.825		48.872	-2.208	9.513	0.000	0.000	1.811	0.085		13.038	0.712	9.131	0.000	0.000	0.000	0.000
SF		1208.749		53.052	-2.319	9.515	0.000	0.000	1.889	0.085		11.822	0.605	9.143	0.000	0.000	0.000	0.000
Q334	F	1210.194		57.369	0.014	9.520	0.000	0.000	1.967	0.001		10.810	-0.018	9.164	0.000	0.000	0.000	0.000
BEND_1		1212.562		48.752	2.230	9.527	0.000	0.000	1.815	-0.083		13.229	-0.756	9.196	0.000	0.000	0.000	0.000
BEND_2		1218.658		26.118	1.483	9.554	0.000	0.000	1.371	-0.062		26.857	-1.479	9.248	0.000	0.000	0.000	0.000
BEND_1		1219.018		25.068	1.439	9.556	0.000	0.000	1.348	-0.062		27.936	-1.522	9.250	0.000	0.000	0.000	0.000
BEND_2		1225.114		12.075	0.692	9.613	0.000	0.000	1.032	-0.042		50.880	-2.241	9.276	0.000	0.000	0.000	0.000
SD		1226.037		10.901	0.579	9.626	0.000	0.000	0.993	-0.042		55.121	-2.351	9.279	0.000	0.000	0.000	0.000
Q333	D	1227.482		9.928	-0.008	9.648	0.000	0.000	0.955	-0.001		59.488	0.021	9.283	0.000	0.000	0.000	0.000
BEND_1		1229.851		12.159	-0.712	9.684	0.000	0.000	1.027	0.040		50.700	2.275	9.290	0.000	0.000	0.000	0.000
BEND_2		1235.947		25.441	-1.467	9.740	0.000	0.000	1.331	0.060		27.471	1.534	9.316	0.000	0.000	0.000	0.000
BEND_1		1236.306		26.511	-1.512	9.742	0.000	0.000	1.353	0.060		26.384	1.490	9.318	0.000	0.000	0.000	0.000
BEND_2		1242.402		49.545	-2.267	9.769	0.000	0.000	1.785	0.081		12.742	0.747	9.372	0.000	0.000	0.000	0.000
SF		1243.326		53.838	-2.381	9.772	0.000	0.000	1.860	0.081		11.466	0.634	9.384	0.000	0.000	0.000	0.000
Q332	F	1244.771		58.303	-0.014	9.776	0.000	0.000	1.933	-0.001		10.366	0.020	9.405	0.000	0.000	0.000	0.000
BEND_1		1247.139		49.662	2.245	9.783	0.000	0.000	1.778	-0.084		12.537	-0.699	9.439	0.000	0.000	0.000	0.000
BEND_2		1253.235		26.809	1.504	9.809	0.000	0.000	1.330	-0.063		25.467	-1.422	9.495	0.000	0.000	0.000	0.000
BEND_1		1253.594		25.744	1.460	9.812	0.000	0.000	1.307	-0.063		26.505	-1.464	9.497	0.000	0.000	0.000	0.000
BEND_2		1259.690		12.464	0.719	9.867	0.000	0.000	0.986	-0.042		48.748	-2.184	9.524	0.000	0.000	0.000	0.000
SD		1260.614		11.241	0.606	9.879	0.000	0.000	0.947	-0.042		52.882	-2.293	9.527	0.000	0.000	0.000	0.000
Q331	D	1262.059		10.202	0.009	9.901	0.000	0.000	0.907	-0.004		57.187	-0.020	9.531	0.000	0.000	0.000	0.000
BEND_1		1264.427		12.373	-0.697	9.935	0.000	0.000	0.969	0.035		48.918	2.152	9.538	0.000	0.000	0.000	0.000
BEND_2		1270.523		25.339	-1.430	9.991	0.000	0.000	1.244	0.056		26.941	1.452	9.565	0.000	0.000	0.000	0.000
BEND_1		1270.883		26.382	-1.473	9.994	0.000	0.000	1.264	0.056		25.913	1.411	9.567	0.000	0.000	0.000	0.000
BEND_2		1276.979		48.800	-2.205	10.021	0.000	0.000	1.667	0.076		12.994	0.708	9.621	0.000	0.000	0.000	0.000
SF		1277.902		52.976	-2.316	10.024	0.000	0.000	1.738	0.076		11.785	0.601	9.633	0.000	0.000	0.000	0.000
Q330	F	1279.347		57.289	0.013	10.028	0.000	0.000	1.807	-0.001		10.783	-0.021	9.654	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_1		1281.716		48.688	2.226	10.035	0.000	0.000	1.664	-0.078		13.213	-0.759	9.686	0.000	0.000	0.000	0.000
BEND_2		1287.812		26.094	1.480	10.062	0.000	0.000	1.252	-0.057		26.888	-1.484	9.738	0.000	0.000	0.000	0.000
BEND_1		1288.171		25.046	1.437	10.064	0.000	0.000	1.232	-0.057		27.970	-1.527	9.740	0.000	0.000	0.000	0.000
BEND_2		1294.267		12.078	0.691	10.121	0.000	0.000	0.947	-0.036		50.994	-2.249	9.766	0.000	0.000	0.000	0.000
SD		1295.191		10.906	0.578	10.134	0.000	0.000	0.914	-0.036		55.250	-2.359	9.769	0.000	0.000	0.000	0.000
Q329	D	1296.636		9.937	-0.009	10.157	0.000	0.000	0.882	0.001		59.636	0.018	9.773	0.000	0.000	0.000	0.000
BEND_1		1299.004		12.176	-0.714	10.192	0.000	0.000	0.953	0.039		50.836	2.279	9.780	0.000	0.000	0.000	0.000
BEND_2		1305.100		25.482	-1.469	10.248	0.000	0.000	1.252	0.059		27.563	1.538	9.806	0.000	0.000	0.000	0.000
BEND_1		1305.460		26.554	-1.514	10.250	0.000	0.000	1.273	0.059		26.473	1.494	9.808	0.000	0.000	0.000	0.000
BEND_2		1311.556		49.615	-2.269	10.277	0.000	0.000	1.699	0.080		12.786	0.751	9.862	0.000	0.000	0.000	0.000
SF		1312.479		53.912	-2.384	10.280	0.000	0.000	1.774	0.080		11.504	0.638	9.874	0.000	0.000	0.000	0.000
Q328	F	1313.924		58.380	-0.013	10.284	0.000	0.000	1.848	0.001		10.394	0.022	9.895	0.000	0.000	0.000	0.000
BEND_1		1316.293		49.723	2.249	10.291	0.000	0.000	1.706	-0.078		12.556	-0.697	9.929	0.000	0.000	0.000	0.000
BEND_2		1322.389		26.831	1.506	10.317	0.000	0.000	1.297	-0.057		25.443	-1.417	9.984	0.000	0.000	0.000	0.000
BEND_1		1322.748		25.764	1.463	10.320	0.000	0.000	1.277	-0.057		26.477	-1.459	9.986	0.000	0.000	0.000	0.000
BEND_2		1328.844		12.460	0.720	10.375	0.000	0.000	0.995	-0.036		48.643	-2.176	10.014	0.000	0.000	0.000	0.000
SD		1329.768		11.234	0.607	10.387	0.000	0.000	0.961	-0.036		52.763	-2.285	10.016	0.000	0.000	0.000	0.000
Q327	D	1331.213		10.192	0.010	10.409	0.000	0.000	0.931	0.004		57.050	-0.017	10.021	0.000	0.000	0.000	0.000
BEND_1		1333.581		12.356	-0.696	10.444	0.000	0.000	1.012	0.043		48.789	2.149	10.028	0.000	0.000	0.000	0.000
BEND_2		1339.677		25.298	-1.428	10.500	0.000	0.000	1.339	0.064		26.852	1.449	10.055	0.000	0.000	0.000	0.000
BEND_1		1340.037		26.340	-1.471	10.502	0.000	0.000	1.362	0.064		25.826	1.407	10.057	0.000	0.000	0.000	0.000
BEND_2		1346.133		48.733	-2.203	10.529	0.000	0.000	1.815	0.085		12.949	0.705	10.111	0.000	0.000	0.000	0.000
SF		1347.056		52.904	-2.314	10.532	0.000	0.000	1.894	0.085		11.746	0.598	10.123	0.000	0.000	0.000	0.000
Q326	F	1348.501		57.214	0.012	10.536	0.000	0.000	1.972	0.001		10.753	-0.023	10.144	0.000	0.000	0.000	0.000
BENDDS_1		1350.741		47.574	3.035	10.543	0.000	0.000	1.799	-0.115		13.392	-0.962	10.174	0.000	0.000	0.000	0.000
BENDDS_2		1354.805		26.454	2.163	10.561	0.000	0.000	1.359	-0.101		23.579	-1.545	10.211	0.000	0.000	0.000	0.000
BENDDS_1		1355.164		24.927	2.085	10.563	0.000	0.000	1.323	-0.101		24.708	-1.596	10.213	0.000	0.000	0.000	0.000
BENDDS_2		1359.228		11.522	1.213	10.602	0.000	0.000	0.940	-0.087		40.048	-2.178	10.234	0.000	0.000	0.000	0.000
Q325	D	1361.467		7.864	0.296	10.640	0.000	0.000	0.780	-0.039		46.497	0.287	10.242	0.000	0.000	0.000	0.000
BENDDS_1		1363.707		8.568	-0.461	10.686	0.000	0.000	0.759	0.005		37.758	2.607	10.250	0.000	0.000	0.000	0.000
BENDDS_2		1367.771		14.655	-1.037	10.745	0.000	0.000	0.807	0.019		19.972	1.769	10.274	0.000	0.000	0.000	0.000
BENDDS_1		1368.130		15.418	-1.087	10.748	0.000	0.000	0.814	0.019		18.727	1.695	10.277	0.000	0.000	0.000	0.000
BENDDS_2		1372.194		26.595	-1.663	10.781	0.000	0.000	0.919	0.033		8.365	0.855	10.329	0.000	0.000	0.000	0.000
Q324	F	1374.434		31.946	-0.025	10.793	0.000	0.000	0.950	-0.024		6.116	0.046	10.381	0.000	0.000	0.000	0.000
BENDDS_1		1376.673		26.792	1.626	10.804	0.000	0.000	0.814	-0.079		7.905	-0.737	10.435	0.000	0.000	0.000	0.000
BENDDS_2		1380.737		15.824	1.073	10.836	0.000	0.000	0.522	-0.065		17.119	-1.530	10.492	0.000	0.000	0.000	0.000
BENDDS_1		1381.097		15.070	1.024	10.840	0.000	0.000	0.498	-0.065		18.244	-1.600	10.495	0.000	0.000	0.000	0.000
BENDDS_2		1385.161		8.990	0.472	10.896	0.000	0.000	0.263	-0.051		34.467	-2.391	10.521	0.000	0.000	0.000	0.000
Q323	D	1387.400		8.244	-0.295	10.939	0.000	0.000	0.157	-0.040		42.523	-0.283	10.530	0.000	0.000	0.000	0.000
BENDDS_1		1389.640		11.933	-1.221	10.977	0.000	0.000	0.079	-0.032		36.728	1.968	10.539	0.000	0.000	0.000	0.000
BENDDS_2		1393.704		25.305	-2.069	11.014	0.000	0.000	-0.024	-0.019		22.920	1.430	10.561	0.000	0.000	0.000	0.000
BENDDS_1		1394.063		26.820	-2.144	11.016	0.000	0.000	-0.031	-0.019		21.910	1.382	10.564	0.000	0.000	0.000	0.000
BENDDS_2		1398.127		47.697	-2.993	11.034	0.000	0.000	-0.078	-0.005		12.868	0.843	10.603	0.000	0.000	0.000	0.000
Q322	F	1400.367		57.123	0.037	11.041	0.000	0.000	-0.084	0.000		10.694	-0.068	10.634	0.000	0.000	0.000	0.000
Q321	D	1417.655		9.700	-0.014	11.172	0.000	0.000	-0.018	0.003		62.587	0.002	10.751	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
MI32		1426.300	25.879	-1.508	11.266	0.000	0.000	0.003	0.002	28.439	1.598	10.783	0.000	0.000	0.000	0.000
Q320	F	1434.944	58.705	-0.037	11.301	0.000	0.000	0.023	0.001	10.641	0.069	10.867	0.000	0.000	0.000	0.000
Q319	D	1452.233	10.438	0.016	11.424	0.000	0.000	0.032	0.002	54.569	0.002	10.995	0.000	0.000	0.000	0.000
BENDDS_1		1454.472	12.794	-0.882	11.456	0.000	0.000	0.039	0.004	45.604	2.829	11.002	0.000	0.000	0.000	0.000
BENDDS_2		1458.536	22.255	-1.446	11.495	0.000	0.000	0.082	0.018	25.866	2.028	11.021	0.000	0.000	0.000	0.000
BENDDS_1		1458.896	23.312	-1.496	11.497	0.000	0.000	0.088	0.018	24.434	1.957	11.023	0.000	0.000	0.000	0.000
BENDDS_2		1462.960	37.768	-2.061	11.519	0.000	0.000	0.188	0.031	11.791	1.154	11.061	0.000	0.000	0.000	0.000
Q318	F	1465.199	43.815	0.312	11.527	0.000	0.000	0.249	0.018	8.369	0.235	11.098	0.000	0.000	0.000	0.000
BENDDS_1		1467.438	35.284	2.524	11.536	0.000	0.000	0.265	0.002	9.439	-0.554	11.140	0.000	0.000	0.000	0.000
BENDDS_2		1471.503	18.217	1.675	11.562	0.000	0.000	0.303	0.016	16.225	-1.116	11.193	0.000	0.000	0.000	0.000
BENDDS_1		1471.862	17.039	1.600	11.565	0.000	0.000	0.309	0.016	17.044	-1.165	11.197	0.000	0.000	0.000	0.000
BENDDS_2		1475.926	7.485	0.751	11.624	0.000	0.000	0.403	0.030	28.798	-1.726	11.226	0.000	0.000	0.000	0.000
Q317	D	1478.165	5.653	-0.029	11.681	0.000	0.000	0.489	0.057	34.274	0.016	11.237	0.000	0.000	0.000	0.000
BENDDS_1		1480.405	7.773	-0.825	11.737	0.000	0.000	0.662	0.088	28.669	1.751	11.248	0.000	0.000	0.000	0.000
BENDDS_2		1484.469	18.044	-1.703	11.793	0.000	0.000	1.048	0.102	16.777	1.175	11.278	0.000	0.000	0.000	0.000
BENDDS_1		1484.828	19.296	-1.780	11.796	0.000	0.000	1.085	0.102	15.951	1.124	11.281	0.000	0.000	0.000	0.000
BENDDS_2		1488.892	37.336	-2.659	11.820	0.000	0.000	1.527	0.116	9.156	0.548	11.336	0.000	0.000	0.000	0.000
Q316	F	1491.132	46.286	-0.311	11.829	0.000	0.000	1.714	0.016	8.107	-0.234	11.379	0.000	0.000	0.000	0.000
BENDDS_1		1493.371	39.809	2.197	11.837	0.000	0.000	1.597	-0.085	11.494	-1.145	11.417	0.000	0.000	0.000	0.000
BENDDS_2		1497.435	24.371	1.602	11.858	0.000	0.000	1.278	-0.072	24.115	-1.961	11.456	0.000	0.000	0.000	0.000
BENDDS_1		1497.795	23.239	1.549	11.860	0.000	0.000	1.252	-0.072	25.551	-2.033	11.459	0.000	0.000	0.000	0.000
BENDDS_2		1501.859	13.062	0.955	11.898	0.000	0.000	0.990	-0.058	45.384	-2.847	11.478	0.000	0.000	0.000	0.000
Q315	D	1504.098	10.419	0.042	11.929	0.000	0.000	0.901	-0.004	54.458	-0.035	11.485	0.000	0.000	0.000	0.000
BEND_1		1506.467	12.442	-0.662	11.963	0.000	0.000	0.961	0.034	46.661	2.033	11.492	0.000	0.000	0.000	0.000
BEND_2		1512.563	24.814	-1.367	12.019	0.000	0.000	1.231	0.055	25.951	1.364	11.520	0.000	0.000	0.000	0.000
BEND_1		1512.922	25.812	-1.409	12.022	0.000	0.000	1.251	0.055	24.985	1.324	11.522	0.000	0.000	0.000	0.000
BEND_2		1519.018	47.285	-2.114	12.049	0.000	0.000	1.649	0.076	12.927	0.653	11.577	0.000	0.000	0.000	0.000
SF		1519.942	51.288	-2.221	12.052	0.000	0.000	1.719	0.076	11.815	0.551	11.589	0.000	0.000	0.000	0.000
Q314	F	1521.387	55.402	0.033	12.057	0.000	0.000	1.787	-0.001	10.952	-0.071	11.610	0.000	0.000	0.000	0.000
BEND_1		1523.755	47.005	2.166	12.064	0.000	0.000	1.645	-0.077	13.663	-0.824	11.641	0.000	0.000	0.000	0.000
BEND_2		1529.851	25.098	1.428	12.092	0.000	0.000	1.239	-0.056	28.275	-1.572	11.692	0.000	0.000	0.000	0.000
BEND_1		1530.211	24.088	1.384	12.095	0.000	0.000	1.219	-0.056	29.421	-1.616	11.694	0.000	0.000	0.000	0.000
BEND_2		1536.307	11.709	0.646	12.154	0.000	0.000	0.940	-0.035	53.671	-2.361	11.718	0.000	0.000	0.000	0.000
SD		1537.230	10.618	0.535	12.167	0.000	0.000	0.908	-0.035	58.136	-2.474	11.721	0.000	0.000	0.000	0.000
Q313	D	1538.675	9.764	-0.044	12.190	0.000	0.000	0.877	0.002	62.722	0.030	11.724	0.000	0.000	0.000	0.000
BENDDS_1		1540.915	12.328	-0.930	12.223	0.000	0.000	0.958	0.054	52.284	3.282	11.731	0.000	0.000	0.000	0.000
BENDDS_2		1544.979	22.386	-1.545	12.263	0.000	0.000	1.205	0.068	29.316	2.369	11.747	0.000	0.000	0.000	0.000
BENDDS_1		1545.338	23.516	-1.599	12.265	0.000	0.000	1.229	0.068	27.643	2.287	11.749	0.000	0.000	0.000	0.000
BENDDS_2		1549.402	39.015	-2.214	12.287	0.000	0.000	1.533	0.082	12.770	1.372	11.784	0.000	0.000	0.000	0.000
Q312	F	1551.642	45.656	0.243	12.295	0.000	0.000	1.644	-0.016	8.540	0.381	11.819	0.000	0.000	0.000	0.000
BENDDS_1		1553.881	37.078	2.576	12.303	0.000	0.000	1.464	-0.111	8.952	-0.397	11.861	0.000	0.000	0.000	0.000
BENDDS_2		1557.945	19.543	1.739	12.328	0.000	0.000	1.040	-0.098	14.316	-0.922	11.920	0.000	0.000	0.000	0.000
BENDDS_1		1558.304	18.320	1.665	12.331	0.000	0.000	1.005	-0.098	14.995	-0.969	11.924	0.000	0.000	0.000	0.000
BENDDS_2		1562.368	8.188	0.828	12.384	0.000	0.000	0.636	-0.084	25.001	-1.493	11.957	0.000	0.000	0.000	0.000
Q311	D	1564.608	6.033	0.033	12.437	0.000	0.000	0.472	-0.053	29.774	0.000	11.970	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BENDDS_1		1566.847	7.854	-0.743	12.491	0.000	0.000	0.391	-0.028	25.000	1.493	11.983	0.000	0.000	0.000	0.000
BENDDS_2		1570.911	17.157	-1.546	12.548	0.000	0.000	0.306	-0.014	14.994	0.969	12.017	0.000	0.000	0.000	0.000
BENDDS_1		1571.271	18.294	-1.617	12.552	0.000	0.000	0.301	-0.014	14.314	0.922	12.020	0.000	0.000	0.000	0.000
BENDDS_2		1575.335	34.703	-2.420	12.577	0.000	0.000	0.273	0.000	8.951	0.397	12.079	0.000	0.000	0.000	0.000
Q310	F	1577.574	42.795	-0.245	12.586	0.000	0.000	0.261	-0.016	8.539	-0.381	12.121	0.000	0.000	0.000	0.000
BENDDS_1		1579.814	36.651	2.057	12.595	0.000	0.000	0.203	-0.031	12.768	-1.372	12.156	0.000	0.000	0.000	0.000
BENDDS_2		1583.878	22.291	1.477	12.618	0.000	0.000	0.106	-0.017	27.641	-2.288	12.191	0.000	0.000	0.000	0.000
BENDDS_1		1584.237	21.247	1.426	12.620	0.000	0.000	0.100	-0.017	29.314	-2.369	12.193	0.000	0.000	0.000	0.000
BENDDS_2		1588.301	12.018	0.846	12.661	0.000	0.000	0.061	-0.003	52.283	-3.283	12.210	0.000	0.000	0.000	0.000
Q309	D	1590.541	9.786	-0.023	12.695	0.000	0.000	0.057	0.000	62.721	-0.030	12.216	0.000	0.000	0.000	0.000
Q308	F	1607.829	59.224	-0.028	12.823	0.000	0.000	0.102	-0.002	10.996	0.069	12.330	0.000	0.000	0.000	0.000
Q307	D	1625.118	10.345	0.024	12.946	0.000	0.000	0.003	-0.006	54.642	0.035	12.455	0.000	0.000	0.000	0.000
Q306	F	1642.407	56.399	0.027	13.072	0.000	0.000	-0.092	-0.002	10.246	-0.067	12.585	0.000	0.000	0.000	0.000
Q305	D	1659.695	9.811	-0.026	13.204	0.000	0.000	-0.057	0.000	62.422	-0.040	12.705	0.000	0.000	0.000	0.000
MI30		1659.695	9.811	-0.026	13.204	0.000	0.000	-0.057	0.000	62.422	-0.040	12.705	0.000	0.000	0.000	0.000
Q304	F	1676.984	59.382	-0.025	13.331	0.000	0.000	-0.098	0.002	11.099	0.064	12.819	0.000	0.000	0.000	0.000
Q303	D	1694.273	10.318	0.027	13.454	0.000	0.000	0.000	0.006	54.981	0.045	12.942	0.000	0.000	0.000	0.000
Q302	F	1711.561	56.249	0.024	13.581	0.000	0.000	0.097	0.002	10.148	-0.060	13.073	0.000	0.000	0.000	0.000
Q301	D	1728.850	9.839	-0.028	13.712	0.000	0.000	0.057	0.000	62.044	-0.049	13.194	0.000	0.000	0.000	0.000
BENDDS_1		1731.089	12.335	-0.913	13.746	0.000	0.000	0.061	0.003	52.036	3.187	13.200	0.000	0.000	0.000	0.000
BENDDS_2		1735.153	22.211	-1.517	13.785	0.000	0.000	0.103	0.017	29.665	2.317	13.217	0.000	0.000	0.000	0.000
BENDDS_1		1735.513	23.321	-1.571	13.788	0.000	0.000	0.109	0.017	28.028	2.240	13.219	0.000	0.000	0.000	0.000
BENDDS_2		1739.577	38.541	-2.175	13.809	0.000	0.000	0.207	0.031	13.364	1.368	13.252	0.000	0.000	0.000	0.000
Q232	F	1741.816	45.045	0.251	13.818	0.000	0.000	0.265	0.016	9.149	0.366	13.286	0.000	0.000	0.000	0.000
BENDDS_1		1744.056	36.541	2.548	13.826	0.000	0.000	0.277	0.000	9.699	-0.433	13.325	0.000	0.000	0.000	0.000
BENDDS_2		1748.120	19.216	1.715	13.851	0.000	0.000	0.305	0.014	15.234	-0.929	13.379	0.000	0.000	0.000	0.000
BENDDS_1		1748.479	18.010	1.641	13.854	0.000	0.000	0.310	0.014	15.918	-0.973	13.383	0.000	0.000	0.000	0.000
BENDDS_2		1752.543	8.058	0.808	13.908	0.000	0.000	0.394	0.028	25.845	-1.469	13.415	0.000	0.000	0.000	0.000
Q231	D	1754.783	5.985	0.018	13.962	0.000	0.000	0.474	0.053	30.415	0.078	13.427	0.000	0.000	0.000	0.000
BENDDS_1		1757.022	7.883	-0.763	14.016	0.000	0.000	0.639	0.084	25.221	1.586	13.440	0.000	0.000	0.000	0.000
BENDDS_2		1761.086	17.400	-1.579	14.073	0.000	0.000	1.008	0.098	14.626	1.020	13.474	0.000	0.000	0.000	0.000
BENDDS_1		1761.446	18.561	-1.651	14.076	0.000	0.000	1.043	0.098	13.911	0.970	13.478	0.000	0.000	0.000	0.000
BENDDS_2		1765.510	35.294	-2.467	14.101	0.000	0.000	1.468	0.112	8.328	0.403	13.540	0.000	0.000	0.000	0.000
Q230	F	1767.749	43.544	-0.252	14.110	0.000	0.000	1.648	0.016	7.884	-0.360	13.585	0.000	0.000	0.000	0.000
BENDDS_1		1769.989	37.301	2.092	14.119	0.000	0.000	1.536	-0.082	11.931	-1.323	13.623	0.000	0.000	0.000	0.000
BENDDS_2		1774.053	22.677	1.506	14.141	0.000	0.000	1.231	-0.068	26.487	-2.259	13.660	0.000	0.000	0.000	0.000
BENDDS_1		1774.412	21.613	1.454	14.144	0.000	0.000	1.207	-0.068	28.140	-2.341	13.662	0.000	0.000	0.000	0.000
BENDDS_2		1778.476	12.172	0.869	14.184	0.000	0.000	0.959	-0.054	50.968	-3.275	13.679	0.000	0.000	0.000	0.000
Q229	D	1780.716	9.851	-0.007	14.217	0.000	0.000	0.876	-0.002	61.508	-0.107	13.685	0.000	0.000	0.000	0.000
BEND_1		1783.084	12.067	-0.709	14.253	0.000	0.000	0.939	0.035	52.969	2.251	13.692	0.000	0.000	0.000	0.000
BEND_2		1789.180	25.331	-1.468	14.310	0.000	0.000	1.216	0.056	29.761	1.555	13.716	0.000	0.000	0.000	0.000
BEND_1		1789.539	26.402	-1.512	14.312	0.000	0.000	1.236	0.056	28.659	1.514	13.718	0.000	0.000	0.000	0.000
BEND_2		1795.635	49.464	-2.271	14.339	0.000	0.000	1.640	0.077	14.464	0.814	13.767	0.000	0.000	0.000	0.000
SF		1796.559	53.765	-2.386	14.342	0.000	0.000	1.711	0.077	13.058	0.708	13.777	0.000	0.000	0.000	0.000
Q228	F	1798.004	58.247	-0.021	14.346	0.000	0.000	1.781	0.001	11.794	0.044	13.796	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_1		1800.372	49.648	2.237	14.353	0.000	0.000	1.643	-0.076	14.008	-0.708	13.826	0.000	0.000	0.000	0.000
BEND_2		1806.468	26.872	1.500	14.379	0.000	0.000	1.246	-0.055	26.622	-1.360	13.877	0.000	0.000	0.000	0.000
BEND_1		1806.828	25.810	1.456	14.381	0.000	0.000	1.227	-0.055	27.614	-1.399	13.879	0.000	0.000	0.000	0.000
BEND_2		1812.924	12.549	0.719	14.436	0.000	0.000	0.957	-0.034	48.631	-2.048	13.906	0.000	0.000	0.000	0.000
SD		1813.847	11.323	0.608	14.449	0.000	0.000	0.926	-0.034	52.505	-2.147	13.909	0.000	0.000	0.000	0.000
Q227	D	1815.292	10.282	0.008	14.470	0.000	0.000	0.897	0.004	56.395	0.110	13.913	0.000	0.000	0.000	0.000
BENDDS_1		1817.532	12.655	-0.885	14.503	0.000	0.000	0.986	0.057	46.698	3.006	13.920	0.000	0.000	0.000	0.000
BENDDS_2		1821.596	22.174	-1.457	14.542	0.000	0.000	1.248	0.071	25.811	2.134	13.939	0.000	0.000	0.000	0.000
BENDDS_1		1821.955	23.240	-1.508	14.544	0.000	0.000	1.274	0.071	24.305	2.056	13.941	0.000	0.000	0.000	0.000
BENDDS_2		1826.019	37.824	-2.081	14.566	0.000	0.000	1.592	0.085	11.141	1.182	13.981	0.000	0.000	0.000	0.000
Q226	F	1828.259	43.959	0.296	14.575	0.000	0.000	1.709	-0.016	7.616	0.268	14.021	0.000	0.000	0.000	0.000
BENDDS_1		1830.498	35.464	2.521	14.583	0.000	0.000	1.523	-0.115	8.454	-0.497	14.067	0.000	0.000	0.000	0.000
BENDDS_2		1834.562	18.398	1.678	14.609	0.000	0.000	1.083	-0.101	14.923	-1.095	14.126	0.000	0.000	0.000	0.000
BENDDS_1		1834.922	17.218	1.604	14.612	0.000	0.000	1.046	-0.101	15.729	-1.148	14.129	0.000	0.000	0.000	0.000
BENDDS_2		1838.986	7.610	0.761	14.670	0.000	0.000	0.662	-0.088	27.491	-1.746	14.161	0.000	0.000	0.000	0.000
Q225	D	1841.225	5.735	-0.021	14.726	0.000	0.000	0.490	-0.056	33.199	-0.088	14.172	0.000	0.000	0.000	0.000
BENDDS_1		1843.465	7.815	-0.813	14.782	0.000	0.000	0.404	-0.030	28.196	1.614	14.184	0.000	0.000	0.000	0.000
BENDDS_2		1847.529	17.932	-1.677	14.838	0.000	0.000	0.312	-0.016	17.187	1.095	14.213	0.000	0.000	0.000	0.000
BENDDS_1		1847.888	19.165	-1.753	14.841	0.000	0.000	0.306	-0.016	16.417	1.049	14.217	0.000	0.000	0.000	0.000
BENDDS_2		1851.952	36.923	-2.617	14.865	0.000	0.000	0.270	-0.002	10.001	0.529	14.268	0.000	0.000	0.000	0.000
Q224	F	1854.192	45.716	-0.295	14.874	0.000	0.000	0.254	-0.018	9.044	-0.275	14.307	0.000	0.000	0.000	0.000
BENDDS_1		1856.431	39.276	2.177	14.882	0.000	0.000	0.194	-0.032	12.759	-1.233	14.341	0.000	0.000	0.000	0.000
BENDDS_2		1860.495	23.993	1.583	14.903	0.000	0.000	0.093	-0.018	26.043	-2.035	14.377	0.000	0.000	0.000	0.000
BENDDS_1		1860.855	22.874	1.531	14.905	0.000	0.000	0.086	-0.018	27.532	-2.106	14.379	0.000	0.000	0.000	0.000
BENDDS_2		1864.919	12.845	0.937	14.943	0.000	0.000	0.042	-0.004	47.904	-2.906	14.397	0.000	0.000	0.000	0.000
Q223	D	1867.158	10.269	0.033	14.975	0.000	0.000	0.035	-0.002	57.000	0.066	14.404	0.000	0.000	0.000	0.000
Q222	F	1884.447	55.907	0.019	15.104	0.000	0.000	0.028	-0.002	9.929	-0.025	14.533	0.000	0.000	0.000	0.000
MI22		1893.091	24.945	1.418	15.140	0.000	0.000	0.005	-0.003	26.587	-1.536	14.624	0.000	0.000	0.000	0.000
Q221	D	1901.735	9.893	-0.034	15.235	0.000	0.000	-0.019	-0.003	59.897	-0.068	14.658	0.000	0.000	0.000	0.000
Q220	F	1919.024	59.859	-0.017	15.361	0.000	0.000	-0.091	0.000	11.376	0.020	14.774	0.000	0.000	0.000	0.000
BENDDS_1		1921.263	49.884	3.156	15.367	0.000	0.000	-0.084	0.005	13.890	-0.935	14.803	0.000	0.000	0.000	0.000
BENDDS_2		1925.327	27.860	2.263	15.384	0.000	0.000	-0.036	0.019	23.719	-1.483	14.839	0.000	0.000	0.000	0.000
BENDDS_1		1925.687	26.262	2.184	15.386	0.000	0.000	-0.029	0.019	24.802	-1.531	14.841	0.000	0.000	0.000	0.000
BENDDS_2		1929.751	12.139	1.291	15.423	0.000	0.000	0.076	0.033	39.470	-2.078	14.862	0.000	0.000	0.000	0.000
Q219	D	1931.990	8.190	0.344	15.460	0.000	0.000	0.154	0.040	45.506	0.348	14.870	0.000	0.000	0.000	0.000
BENDDS_1		1934.230	8.705	-0.417	15.504	0.000	0.000	0.260	0.051	36.695	2.598	14.879	0.000	0.000	0.000	0.000
BENDDS_2		1938.294	14.322	-0.965	15.563	0.000	0.000	0.495	0.065	19.061	1.741	14.903	0.000	0.000	0.000	0.000
BENDDS_1		1938.653	15.033	-1.014	15.567	0.000	0.000	0.519	0.065	17.838	1.665	14.906	0.000	0.000	0.000	0.000
BENDDS_2		1942.717	25.499	-1.562	15.600	0.000	0.000	0.810	0.079	7.797	0.806	14.962	0.000	0.000	0.000	0.000
Q218	F	1944.957	30.489	0.002	15.613	0.000	0.000	0.947	0.024	5.755	0.008	15.018	0.000	0.000	0.000	0.000
BENDDS_1		1947.196	25.482	1.565	15.625	0.000	0.000	0.916	-0.032	7.720	-0.786	15.074	0.000	0.000	0.000	0.000
BENDDS_2		1951.260	14.998	1.015	15.658	0.000	0.000	0.813	-0.019	17.568	-1.637	15.131	0.000	0.000	0.000	0.000
BENDDS_1		1951.620	14.286	0.966	15.662	0.000	0.000	0.806	-0.019	18.772	-1.712	15.134	0.000	0.000	0.000	0.000
BENDDS_2		1955.684	8.668	0.416	15.722	0.000	0.000	0.759	-0.005	36.144	-2.562	15.159	0.000	0.000	0.000	0.000
Q217	D	1957.923	8.157	-0.344	15.766	0.000	0.000	0.781	0.040	44.840	-0.347	15.167	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BENDDS_1		1960.163	12.103	-1.291	15.803	0.000	0.000	0.942	0.088	38.914	2.042	15.176	0.000	0.000	0.000	0.000
BENDDS_2		1964.227	26.229	-2.186	15.840	0.000	0.000	1.327	0.102	24.503	1.503	15.197	0.000	0.000	0.000	0.000
BENDDS_1		1964.586	27.829	-2.265	15.842	0.000	0.000	1.363	0.102	23.439	1.456	15.199	0.000	0.000	0.000	0.000
BENDDS_2		1968.650	49.873	-3.160	15.859	0.000	0.000	1.805	0.116	13.802	0.915	15.235	0.000	0.000	0.000	0.000
Q216	F	1970.890	59.866	0.013	15.865	0.000	0.000	1.978	-0.001	11.366	-0.035	15.265	0.000	0.000	0.000	0.000
BEND_1		1973.258	50.875	2.329	15.872	0.000	0.000	1.822	-0.085	13.939	-0.792	15.295	0.000	0.000	0.000	0.000
BEND_2		1979.354	27.175	1.559	15.898	0.000	0.000	1.366	-0.064	27.921	-1.501	15.345	0.000	0.000	0.000	0.000
BEND_1		1979.714	26.071	1.514	15.900	0.000	0.000	1.343	-0.064	29.015	-1.543	15.347	0.000	0.000	0.000	0.000
BEND_2		1985.810	12.307	0.744	15.956	0.000	0.000	1.015	-0.043	52.145	-2.250	15.372	0.000	0.000	0.000	0.000
SD		1986.733	11.040	0.628	15.968	0.000	0.000	0.975	-0.043	56.400	-2.358	15.375	0.000	0.000	0.000	0.000
Q215	D	1988.178	9.937	0.035	15.991	0.000	0.000	0.934	-0.004	60.725	0.070	15.379	0.000	0.000	0.000	0.000
BEND_1		1990.547	11.948	-0.661	16.026	0.000	0.000	0.998	0.036	51.540	2.363	15.386	0.000	0.000	0.000	0.000
BEND_2		1996.643	24.473	-1.394	16.084	0.000	0.000	1.280	0.057	27.459	1.586	15.412	0.000	0.000	0.000	0.000
BEND_1		1997.002	25.491	-1.437	16.086	0.000	0.000	1.300	0.057	26.335	1.540	15.414	0.000	0.000	0.000	0.000
BEND_2		2003.098	47.479	-2.170	16.114	0.000	0.000	1.710	0.078	12.308	0.760	15.469	0.000	0.000	0.000	0.000
SF		2004.021	51.590	-2.281	16.117	0.000	0.000	1.781	0.078	11.013	0.642	15.481	0.000	0.000	0.000	0.000
Q214	F	2005.466	55.869	-0.014	16.122	0.000	0.000	1.852	-0.002	9.881	0.040	15.504	0.000	0.000	0.000	0.000
BEND_1		2007.835	47.603	2.147	16.129	0.000	0.000	1.703	-0.081	11.895	-0.664	15.539	0.000	0.000	0.000	0.000
BEND_2		2013.931	25.805	1.429	16.157	0.000	0.000	1.275	-0.060	24.490	-1.401	15.597	0.000	0.000	0.000	0.000
BEND_1		2014.290	24.793	1.386	16.159	0.000	0.000	1.253	-0.060	25.513	-1.445	15.600	0.000	0.000	0.000	0.000
BEND_2		2020.386	12.270	0.668	16.216	0.000	0.000	0.953	-0.039	47.609	-2.179	15.628	0.000	0.000	0.000	0.000
SD		2021.310	11.137	0.559	16.228	0.000	0.000	0.917	-0.039	51.737	-2.291	15.631	0.000	0.000	0.000	0.000
Q213	D	2022.755	10.226	-0.034	16.250	0.000	0.000	0.881	-0.001	56.091	-0.068	15.635	0.000	0.000	0.000	0.000
BEND_1		2025.123	12.622	-0.750	16.284	0.000	0.000	0.946	0.036	48.192	2.070	15.642	0.000	0.000	0.000	0.000
BEND_2		2031.219	26.357	-1.504	16.338	0.000	0.000	1.228	0.057	27.012	1.403	15.669	0.000	0.000	0.000	0.000
BEND_1		2031.579	27.453	-1.548	16.340	0.000	0.000	1.248	0.057	26.018	1.364	15.671	0.000	0.000	0.000	0.000
BEND_2		2037.675	50.926	-2.302	16.367	0.000	0.000	1.658	0.078	13.467	0.695	15.724	0.000	0.000	0.000	0.000
SF		2038.598	55.284	-2.417	16.369	0.000	0.000	1.729	0.078	12.278	0.593	15.735	0.000	0.000	0.000	0.000
Q212	F	2040.043	59.782	0.016	16.373	0.000	0.000	1.800	0.001	11.312	-0.044	15.755	0.000	0.000	0.000	0.000
BEND_1		2042.412	50.788	2.328	16.380	0.000	0.000	1.661	-0.076	13.925	-0.801	15.786	0.000	0.000	0.000	0.000
BEND_2		2048.508	27.101	1.558	16.406	0.000	0.000	1.259	-0.055	28.065	-1.518	15.836	0.000	0.000	0.000	0.000
BEND_1		2048.867	25.998	1.512	16.408	0.000	0.000	1.240	-0.055	29.171	-1.560	15.838	0.000	0.000	0.000	0.000
BEND_2		2054.963	12.260	0.742	16.464	0.000	0.000	0.965	-0.035	52.552	-2.274	15.863	0.000	0.000	0.000	0.000
SD		2055.887	10.998	0.625	16.477	0.000	0.000	0.933	-0.035	56.853	-2.383	15.865	0.000	0.000	0.000	0.000
Q211	D	2057.332	9.902	0.033	16.499	0.000	0.000	0.904	0.004	61.231	0.065	15.869	0.000	0.000	0.000	0.000
BEND_1		2059.700	11.918	-0.662	16.534	0.000	0.000	0.983	0.042	51.994	2.379	15.876	0.000	0.000	0.000	0.000
BEND_2		2065.796	24.473	-1.398	16.593	0.000	0.000	1.304	0.063	27.734	1.600	15.901	0.000	0.000	0.000	0.000
BEND_1		2066.156	25.493	-1.441	16.595	0.000	0.000	1.327	0.063	26.601	1.554	15.904	0.000	0.000	0.000	0.000
BEND_2		2072.252	47.545	-2.177	16.623	0.000	0.000	1.775	0.084	12.419	0.772	15.958	0.000	0.000	0.000	0.000
SF		2073.175	51.669	-2.288	16.626	0.000	0.000	1.852	0.084	11.103	0.653	15.971	0.000	0.000	0.000	0.000
Q210	F	2074.620	55.964	-0.018	16.630	0.000	0.000	1.930	0.002	9.941	0.048	15.993	0.000	0.000	0.000	0.000
BEND_1		2076.989	47.698	2.148	16.637	0.000	0.000	1.782	-0.081	11.918	-0.655	16.028	0.000	0.000	0.000	0.000
BEND_2		2083.085	25.882	1.431	16.665	0.000	0.000	1.352	-0.060	24.360	-1.385	16.086	0.000	0.000	0.000	0.000
BEND_1		2083.444	24.869	1.388	16.667	0.000	0.000	1.330	-0.060	25.372	-1.428	16.089	0.000	0.000	0.000	0.000
BEND_2		2089.540	12.317	0.671	16.724	0.000	0.000	1.027	-0.039	47.222	-2.155	16.117	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
SD		2090.464	11.178	0.562	16.736	0.000	0.000	0.991	-0.039	51.305	-2.266	16.120	0.000	0.000	0.000	0.000
Q209	D	2091.909	10.260	-0.032	16.758	0.000	0.000	0.956	0.001	55.606	-0.062	16.124	0.000	0.000	0.000	0.000
BEND_1		2094.277	12.650	-0.748	16.792	0.000	0.000	1.033	0.042	47.754	2.056	16.131	0.000	0.000	0.000	0.000
BEND_2		2100.373	26.352	-1.500	16.846	0.000	0.000	1.352	0.063	26.740	1.390	16.159	0.000	0.000	0.000	0.000
BEND_1		2100.732	27.446	-1.544	16.848	0.000	0.000	1.375	0.063	25.755	1.351	16.161	0.000	0.000	0.000	0.000
BEND_2		2106.828	50.851	-2.296	16.874	0.000	0.000	1.821	0.084	13.352	0.683	16.214	0.000	0.000	0.000	0.000
SF		2107.752	55.196	-2.409	16.877	0.000	0.000	1.898	0.084	12.184	0.582	16.226	0.000	0.000	0.000	0.000
Q208	F	2109.197	59.676	0.019	16.881	0.000	0.000	1.974	-0.001	11.247	-0.052	16.246	0.000	0.000	0.000	0.000
BEND_1		2111.565	50.684	2.327	16.888	0.000	0.000	1.817	-0.085	13.894	-0.809	16.276	0.000	0.000	0.000	0.000
BEND_2		2117.661	27.021	1.555	16.914	0.000	0.000	1.362	-0.064	28.179	-1.534	16.326	0.000	0.000	0.000	0.000
BEND_1		2118.021	25.919	1.510	16.916	0.000	0.000	1.339	-0.064	29.296	-1.576	16.328	0.000	0.000	0.000	0.000
BEND_2		2124.117	12.214	0.739	16.972	0.000	0.000	1.011	-0.043	52.917	-2.298	16.353	0.000	0.000	0.000	0.000
SD		2125.040	10.957	0.622	16.985	0.000	0.000	0.971	-0.043	57.263	-2.407	16.356	0.000	0.000	0.000	0.000
Q207	D	2126.485	9.869	0.031	17.007	0.000	0.000	0.930	-0.004	61.693	0.058	16.360	0.000	0.000	0.000	0.000
BEND_1		2128.854	11.891	-0.664	17.043	0.000	0.000	0.993	0.036	52.415	2.392	16.366	0.000	0.000	0.000	0.000
BEND_2		2134.950	24.482	-1.402	17.101	0.000	0.000	1.274	0.056	28.002	1.612	16.391	0.000	0.000	0.000	0.000
BEND_1		2135.309	25.505	-1.446	17.103	0.000	0.000	1.294	0.056	26.860	1.566	16.394	0.000	0.000	0.000	0.000
BEND_2		2141.405	47.629	-2.184	17.131	0.000	0.000	1.701	0.077	12.538	0.783	16.447	0.000	0.000	0.000	0.000
SF		2142.329	51.766	-2.296	17.134	0.000	0.000	1.773	0.077	11.201	0.664	16.460	0.000	0.000	0.000	0.000
Q206	F	2143.774	56.079	-0.021	17.138	0.000	0.000	1.843	-0.001	10.011	0.056	16.482	0.000	0.000	0.000	0.000
BEND_1		2146.142	47.809	2.150	17.146	0.000	0.000	1.695	-0.080	11.957	-0.648	16.517	0.000	0.000	0.000	0.000
BEND_2		2152.238	25.965	1.433	17.173	0.000	0.000	1.270	-0.059	24.262	-1.370	16.575	0.000	0.000	0.000	0.000
BEND_1		2152.598	24.950	1.391	17.176	0.000	0.000	1.248	-0.059	25.262	-1.413	16.578	0.000	0.000	0.000	0.000
BEND_2		2158.694	12.363	0.674	17.232	0.000	0.000	0.950	-0.038	46.880	-2.133	16.606	0.000	0.000	0.000	0.000
SD		2159.617	11.219	0.565	17.244	0.000	0.000	0.915	-0.038	50.920	-2.242	16.609	0.000	0.000	0.000	0.000
Q205	D	2161.062	10.292	-0.030	17.266	0.000	0.000	0.879	-0.001	55.169	-0.055	16.613	0.000	0.000	0.000	0.000
BEND_1		2163.431	12.675	-0.746	17.300	0.000	0.000	0.945	0.036	47.353	2.044	16.621	0.000	0.000	0.000	0.000
BEND_2		2169.527	26.338	-1.495	17.354	0.000	0.000	1.229	0.057	26.477	1.379	16.648	0.000	0.000	0.000	0.000
BEND_1		2169.886	27.429	-1.539	17.356	0.000	0.000	1.250	0.057	25.500	1.340	16.650	0.000	0.000	0.000	0.000
BEND_2		2175.982	50.759	-2.288	17.382	0.000	0.000	1.661	0.078	13.230	0.672	16.704	0.000	0.000	0.000	0.000
SF		2176.906	55.090	-2.402	17.385	0.000	0.000	1.733	0.078	12.081	0.571	16.716	0.000	0.000	0.000	0.000
Q204	F	2178.351	59.552	0.023	17.389	0.000	0.000	1.805	0.001	11.171	-0.059	16.736	0.000	0.000	0.000	0.000
BEND_1		2180.719	50.566	2.324	17.396	0.000	0.000	1.665	-0.076	13.847	-0.816	16.767	0.000	0.000	0.000	0.000
BEND_2		2186.815	26.935	1.552	17.422	0.000	0.000	1.264	-0.055	28.261	-1.548	16.817	0.000	0.000	0.000	0.000
BEND_1		2187.175	25.835	1.507	17.424	0.000	0.000	1.244	-0.055	29.389	-1.591	16.819	0.000	0.000	0.000	0.000
BEND_2		2193.271	12.168	0.735	17.480	0.000	0.000	0.969	-0.035	53.234	-2.320	16.843	0.000	0.000	0.000	0.000
SD		2194.194	10.918	0.618	17.493	0.000	0.000	0.937	-0.035	57.621	-2.430	16.846	0.000	0.000	0.000	0.000
Q203	D	2195.639	9.838	0.029	17.516	0.000	0.000	0.908	0.004	62.103	0.051	16.850	0.000	0.000	0.000	0.000
BEND_1		2198.008	11.868	-0.666	17.551	0.000	0.000	0.988	0.042	52.795	2.402	16.856	0.000	0.000	0.000	0.000
BEND_2		2204.104	24.501	-1.407	17.609	0.000	0.000	1.311	0.063	28.259	1.622	16.882	0.000	0.000	0.000	0.000
BEND_1		2204.463	25.528	-1.450	17.612	0.000	0.000	1.333	0.063	27.109	1.576	16.884	0.000	0.000	0.000	0.000
BEND_2		2210.559	47.729	-2.192	17.640	0.000	0.000	1.783	0.084	12.663	0.793	16.937	0.000	0.000	0.000	0.000
SF		2211.482	51.881	-2.304	17.643	0.000	0.000	1.861	0.084	11.307	0.675	16.949	0.000	0.000	0.000	0.000
Q202	F	2212.927	56.213	-0.024	17.647	0.000	0.000	1.938	0.001	10.092	0.063	16.971	0.000	0.000	0.000	0.000
BEND_1		2215.296	47.935	2.153	17.654	0.000	0.000	1.790	-0.081	12.011	-0.642	17.006	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_2		2221.392		26.054	1.436	17.682	0.000	0.000	1.357	-0.061		24.196	-1.357	17.064	0.000	0.000	0.000	0.000
BEND_1		2221.751		25.037	1.394	17.684	0.000	0.000	1.335	-0.061		25.186	-1.399	17.067	0.000	0.000	0.000	0.000
BEND_2		2227.847		12.408	0.677	17.740	0.000	0.000	1.029	-0.040		46.590	-2.111	17.095	0.000	0.000	0.000	0.000
SD		2228.771		11.257	0.569	17.752	0.000	0.000	0.993	-0.040		50.589	-2.220	17.098	0.000	0.000	0.000	0.000
Q201	D	2230.216		10.322	-0.028	17.774	0.000	0.000	0.957	0.001		54.788	-0.047	17.103	0.000	0.000	0.000	0.000
MI20		2230.216		10.322	-0.028	17.774	0.000	0.000	0.957	0.001		54.788	-0.047	17.103	0.000	0.000	0.000	0.000
BEND_1		2232.584		12.695	-0.744	17.808	0.000	0.000	1.034	0.042		46.994	2.036	17.110	0.000	0.000	0.000	0.000
BEND_2		2238.680		26.314	-1.490	17.862	0.000	0.000	1.351	0.062		26.228	1.370	17.138	0.000	0.000	0.000	0.000
BEND_1		2239.040		27.401	-1.534	17.864	0.000	0.000	1.373	0.062		25.257	1.331	17.140	0.000	0.000	0.000	0.000
BEND_2		2245.136		50.651	-2.280	17.890	0.000	0.000	1.817	0.083		13.102	0.663	17.194	0.000	0.000	0.000	0.000
SF		2246.059		54.967	-2.393	17.893	0.000	0.000	1.894	0.083		11.972	0.561	17.206	0.000	0.000	0.000	0.000
Q130	F	2247.504		59.410	0.025	17.897	0.000	0.000	1.969	-0.001		11.086	-0.066	17.226	0.000	0.000	0.000	0.000
BEND_1		2249.873		50.433	2.321	17.904	0.000	0.000	1.813	-0.085		13.785	-0.822	17.257	0.000	0.000	0.000	0.000
BEND_2		2255.969		26.844	1.549	17.930	0.000	0.000	1.358	-0.064		28.310	-1.561	17.307	0.000	0.000	0.000	0.000
BEND_1		2256.328		25.747	1.503	17.932	0.000	0.000	1.335	-0.064		29.448	-1.604	17.309	0.000	0.000	0.000	0.000
BEND_2		2262.424		12.123	0.732	17.989	0.000	0.000	1.007	-0.043		53.498	-2.340	17.334	0.000	0.000	0.000	0.000
SD		2263.348		10.880	0.615	18.001	0.000	0.000	0.967	-0.043		57.924	-2.452	17.337	0.000	0.000	0.000	0.000
Q129	D	2264.793		9.810	0.026	18.024	0.000	0.000	0.926	-0.004		62.455	0.043	17.340	0.000	0.000	0.000	0.000
BEND_1		2267.161		11.850	-0.668	18.060	0.000	0.000	0.989	0.035		53.130	2.409	17.347	0.000	0.000	0.000	0.000
BEND_2		2273.257		24.529	-1.412	18.118	0.000	0.000	1.267	0.056		28.500	1.630	17.372	0.000	0.000	0.000	0.000
BEND_1		2273.617		25.560	-1.456	18.120	0.000	0.000	1.288	0.056		27.344	1.584	17.374	0.000	0.000	0.000	0.000
BEND_2		2279.713		47.845	-2.200	18.148	0.000	0.000	1.693	0.077		12.792	0.803	17.427	0.000	0.000	0.000	0.000
SF		2280.636		52.012	-2.313	18.151	0.000	0.000	1.765	0.077		11.419	0.684	17.439	0.000	0.000	0.000	0.000
Q128	F	2282.081		56.363	-0.027	18.155	0.000	0.000	1.834	-0.001		10.181	0.068	17.461	0.000	0.000	0.000	0.000
BEND_1		2284.450		48.075	2.157	18.162	0.000	0.000	1.687	-0.080		12.080	-0.637	17.495	0.000	0.000	0.000	0.000
BEND_2		2290.546		26.147	1.440	18.190	0.000	0.000	1.265	-0.059		24.164	-1.345	17.553	0.000	0.000	0.000	0.000
BEND_1		2290.905		25.127	1.398	18.192	0.000	0.000	1.244	-0.059		25.145	-1.387	17.556	0.000	0.000	0.000	0.000
BEND_2		2297.001		12.452	0.681	18.248	0.000	0.000	0.948	-0.038		46.354	-2.092	17.584	0.000	0.000	0.000	0.000
SD		2297.925		11.294	0.573	18.260	0.000	0.000	0.913	-0.038		50.317	-2.199	17.587	0.000	0.000	0.000	0.000
Q127	D	2299.370		10.349	-0.025	18.282	0.000	0.000	0.878	-0.001		54.468	-0.038	17.592	0.000	0.000	0.000	0.000
BEND_1		2301.738		12.712	-0.741	18.316	0.000	0.000	0.945	0.037		46.685	2.030	17.599	0.000	0.000	0.000	0.000
BEND_2		2307.834		26.281	-1.485	18.370	0.000	0.000	1.232	0.057		25.996	1.363	17.627	0.000	0.000	0.000	0.000
BEND_1		2308.193		27.364	-1.528	18.372	0.000	0.000	1.252	0.057		25.030	1.324	17.629	0.000	0.000	0.000	0.000
BEND_2		2314.289		50.528	-2.272	18.398	0.000	0.000	1.666	0.078		12.972	0.654	17.684	0.000	0.000	0.000	0.000
SF		2315.213		54.828	-2.384	18.401	0.000	0.000	1.738	0.078		11.857	0.552	17.696	0.000	0.000	0.000	0.000
Q126	F	2316.658		59.252	0.028	18.405	0.000	0.000	1.810	0.001		10.993	-0.071	17.717	0.000	0.000	0.000	0.000
BEND_1		2319.026		50.287	2.317	18.412	0.000	0.000	1.670	-0.076		13.709	-0.826	17.748	0.000	0.000	0.000	0.000
BEND_2		2325.122		26.749	1.545	18.438	0.000	0.000	1.268	-0.056		28.326	-1.572	17.798	0.000	0.000	0.000	0.000
BEND_1		2325.482		25.655	1.499	18.440	0.000	0.000	1.248	-0.056		29.471	-1.616	17.800	0.000	0.000	0.000	0.000
BEND_2		2331.578		12.080	0.728	18.497	0.000	0.000	0.973	-0.035		53.704	-2.359	17.824	0.000	0.000	0.000	0.000
SD		2332.501		10.844	0.611	18.510	0.000	0.000	0.941	-0.035		58.165	-2.472	17.827	0.000	0.000	0.000	0.000
Q125	D	2333.946		9.784	0.024	18.532	0.000	0.000	0.912	0.004		62.742	0.034	17.831	0.000	0.000	0.000	0.000
BEND_1		2336.315		11.836	-0.671	18.568	0.000	0.000	0.992	0.043		53.412	2.413	17.837	0.000	0.000	0.000	0.000
BEND_2		2342.411		24.567	-1.418	18.626	0.000	0.000	1.317	0.064		28.721	1.636	17.862	0.000	0.000	0.000	0.000
BEND_1		2342.770		25.602	-1.462	18.629	0.000	0.000	1.339	0.064		27.561	1.590	17.864	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_2		2348.866	47.975	-2.209	18.656	0.000	0.000	1.791	0.084	12.923	0.810	17.917	0.000	0.000	0.000	0.000
SF		2349.790	52.158	-2.322	18.659	0.000	0.000	1.869	0.084	11.535	0.692	17.929	0.000	0.000	0.000	0.000
Q124	F	2351.235	56.529	-0.029	18.664	0.000	0.000	1.947	0.001	10.277	0.073	17.950	0.000	0.000	0.000	0.000
BEND_1		2353.603	48.226	2.162	18.671	0.000	0.000	1.797	-0.082	12.163	-0.634	17.985	0.000	0.000	0.000	0.000
BEND_2		2359.699	26.243	1.445	18.698	0.000	0.000	1.361	-0.061	24.165	-1.335	18.042	0.000	0.000	0.000	0.000
BEND_1		2360.059	25.220	1.402	18.700	0.000	0.000	1.340	-0.061	25.140	-1.376	18.045	0.000	0.000	0.000	0.000
BEND_2		2366.155	12.494	0.685	18.756	0.000	0.000	1.031	-0.040	46.179	-2.075	18.073	0.000	0.000	0.000	0.000
SD		2367.078	11.329	0.577	18.768	0.000	0.000	0.994	-0.040	50.108	-2.181	18.076	0.000	0.000	0.000	0.000
Q123	D	2368.523	10.373	-0.022	18.790	0.000	0.000	0.958	0.000	54.215	-0.029	18.081	0.000	0.000	0.000	0.000
BEND_1		2370.892	12.723	-0.738	18.824	0.000	0.000	1.034	0.041	46.430	2.028	18.088	0.000	0.000	0.000	0.000
BEND_2		2376.988	26.239	-1.479	18.878	0.000	0.000	1.348	0.062	25.786	1.358	18.116	0.000	0.000	0.000	0.000
BEND_1		2377.347	27.318	-1.522	18.880	0.000	0.000	1.370	0.062	24.824	1.319	18.119	0.000	0.000	0.000	0.000
BEND_2		2383.443	50.391	-2.263	18.906	0.000	0.000	1.812	0.083	12.840	0.647	18.174	0.000	0.000	0.000	0.000
SF		2384.367	54.674	-2.375	18.909	0.000	0.000	1.888	0.083	11.740	0.545	18.186	0.000	0.000	0.000	0.000
Q122	F	2385.812	59.078	0.030	18.913	0.000	0.000	1.964	-0.001	10.894	-0.075	18.207	0.000	0.000	0.000	0.000
BEND_1		2388.180	50.130	2.312	18.920	0.000	0.000	1.807	-0.085	13.620	-0.828	18.238	0.000	0.000	0.000	0.000
BEND_2		2394.276	26.651	1.540	18.946	0.000	0.000	1.353	-0.064	28.307	-1.581	18.289	0.000	0.000	0.000	0.000
BEND_1		2394.636	25.561	1.495	18.949	0.000	0.000	1.330	-0.064	29.459	-1.625	18.291	0.000	0.000	0.000	0.000
BEND_2		2400.732	12.039	0.723	19.005	0.000	0.000	1.003	-0.043	53.849	-2.375	18.315	0.000	0.000	0.000	0.000
SD		2401.655	10.811	0.607	19.018	0.000	0.000	0.963	-0.043	58.340	-2.489	18.318	0.000	0.000	0.000	0.000
Q121	D	2403.100	9.761	0.020	19.041	0.000	0.000	0.922	-0.004	62.960	0.024	18.321	0.000	0.000	0.000	0.000
BEND_1		2405.469	11.827	-0.674	19.077	0.000	0.000	0.984	0.035	53.639	2.414	18.328	0.000	0.000	0.000	0.000
BEND_2		2411.565	24.614	-1.424	19.135	0.000	0.000	1.261	0.056	28.919	1.640	18.352	0.000	0.000	0.000	0.000
BEND_1		2411.924	25.653	-1.468	19.137	0.000	0.000	1.282	0.056	27.757	1.594	18.355	0.000	0.000	0.000	0.000
BEND_2		2418.020	48.118	-2.218	19.165	0.000	0.000	1.686	0.077	13.054	0.817	18.406	0.000	0.000	0.000	0.000
SF		2418.943	52.318	-2.331	19.168	0.000	0.000	1.757	0.077	11.654	0.699	18.418	0.000	0.000	0.000	0.000
Q120	F	2420.388	56.709	-0.031	19.172	0.000	0.000	1.826	-0.001	10.379	0.077	18.440	0.000	0.000	0.000	0.000
BEND_1		2422.757	48.388	2.167	19.179	0.000	0.000	1.680	-0.079	12.259	-0.632	18.474	0.000	0.000	0.000	0.000
BEND_2		2428.853	26.342	1.450	19.206	0.000	0.000	1.260	-0.058	24.201	-1.327	18.531	0.000	0.000	0.000	0.000
BEND_1		2429.212	25.316	1.407	19.209	0.000	0.000	1.239	-0.058	25.170	-1.368	18.534	0.000	0.000	0.000	0.000
BEND_2		2435.308	12.534	0.690	19.264	0.000	0.000	0.947	-0.038	46.066	-2.060	18.562	0.000	0.000	0.000	0.000
SD		2436.232	11.361	0.581	19.276	0.000	0.000	0.912	-0.038	49.967	-2.165	18.565	0.000	0.000	0.000	0.000
Q119	D	2437.677	10.394	-0.019	19.298	0.000	0.000	0.878	0.000	54.032	-0.019	18.570	0.000	0.000	0.000	0.000
BEND_1		2440.045	12.730	-0.735	19.331	0.000	0.000	0.946	0.037	46.233	2.028	18.577	0.000	0.000	0.000	0.000
BEND_2		2446.141	26.188	-1.473	19.386	0.000	0.000	1.234	0.058	25.601	1.356	18.606	0.000	0.000	0.000	0.000
BEND_1		2446.501	27.262	-1.516	19.388	0.000	0.000	1.255	0.058	24.641	1.316	18.608	0.000	0.000	0.000	0.000
BEND_2		2452.597	50.242	-2.254	19.414	0.000	0.000	1.671	0.079	12.710	0.641	18.664	0.000	0.000	0.000	0.000
SF		2453.520	54.508	-2.366	19.417	0.000	0.000	1.744	0.079	11.621	0.538	18.676	0.000	0.000	0.000	0.000
Q118	F	2454.965	58.892	0.032	19.421	0.000	0.000	1.816	0.001	10.790	-0.078	18.697	0.000	0.000	0.000	0.000
BEND_1		2457.334	49.964	2.306	19.428	0.000	0.000	1.676	-0.077	13.519	-0.829	18.729	0.000	0.000	0.000	0.000
BEND_2		2463.430	26.552	1.535	19.454	0.000	0.000	1.274	-0.056	28.254	-1.588	18.779	0.000	0.000	0.000	0.000
BEND_1		2463.789	25.465	1.490	19.457	0.000	0.000	1.254	-0.056	29.411	-1.633	18.781	0.000	0.000	0.000	0.000
BEND_2		2469.885	12.001	0.719	19.513	0.000	0.000	0.978	-0.035	53.930	-2.389	18.806	0.000	0.000	0.000	0.000
SD		2470.809	10.780	0.602	19.526	0.000	0.000	0.946	-0.035	58.448	-2.503	18.808	0.000	0.000	0.000	0.000
Q117	D	2472.254	9.742	0.017	19.549	0.000	0.000	0.916	0.004	63.106	0.014	18.812	0.000	0.000	0.000	0.000

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_1		2474.622		11.822	-0.678	19.585	0.000	0.000	0.997	0.043		53.805	2.412	18.818	0.000	0.000	0.000	0.000
BEND_2		2480.718		24.669	-1.430	19.643	0.000	0.000	1.322	0.064		29.091	1.641	18.843	0.000	0.000	0.000	0.000
BEND_1		2481.078		25.713	-1.474	19.645	0.000	0.000	1.345	0.064		27.927	1.596	18.845	0.000	0.000	0.000	0.000
BEND_2		2487.174		48.272	-2.227	19.673	0.000	0.000	1.798	0.085		13.183	0.822	18.896	0.000	0.000	0.000	0.000
SF		2488.097		52.490	-2.341	19.676	0.000	0.000	1.876	0.085		11.772	0.705	18.908	0.000	0.000	0.000	0.000
Q116	F	2489.542		56.901	-0.033	19.680	0.000	0.000	1.954	0.001		10.484	0.079	18.929	0.000	0.000	0.000	0.000
BEND_1		2491.911		48.558	2.173	19.687	0.000	0.000	1.804	-0.082		12.365	-0.632	18.963	0.000	0.000	0.000	0.000
BEND_2		2498.007		26.442	1.455	19.714	0.000	0.000	1.366	-0.061		24.271	-1.321	19.020	0.000	0.000	0.000	0.000
BEND_1		2498.366		25.412	1.413	19.717	0.000	0.000	1.343	-0.061		25.235	-1.361	19.023	0.000	0.000	0.000	0.000
BEND_2		2504.462		12.571	0.694	19.772	0.000	0.000	1.032	-0.041		46.017	-2.047	19.051	0.000	0.000	0.000	0.000
SD		2505.386		11.390	0.585	19.784	0.000	0.000	0.995	-0.041		49.894	-2.151	19.054	0.000	0.000	0.000	0.000
Q115	D	2506.831		10.412	-0.016	19.806	0.000	0.000	0.958	0.000		53.924	-0.009	19.059	0.000	0.000	0.000	0.000
BEND_1		2509.199		12.732	-0.731	19.839	0.000	0.000	1.033	0.041		46.098	2.032	19.066	0.000	0.000	0.000	0.000
BEND_2		2515.295		26.129	-1.466	19.894	0.000	0.000	1.345	0.062		25.444	1.355	19.095	0.000	0.000	0.000	0.000
BEND_1		2515.654		27.198	-1.510	19.896	0.000	0.000	1.367	0.062		24.484	1.315	19.097	0.000	0.000	0.000	0.000
BEND_2		2521.750		50.082	-2.245	19.922	0.000	0.000	1.806	0.082		12.584	0.636	19.153	0.000	0.000	0.000	0.000
SF		2522.674		54.331	-2.356	19.925	0.000	0.000	1.882	0.082		11.504	0.533	19.166	0.000	0.000	0.000	0.000
Q114	F	2524.119		58.695	0.034	19.929	0.000	0.000	1.957	-0.001		10.684	-0.079	19.187	0.000	0.000	0.000	0.000
BEND_1		2526.487		49.789	2.299	19.936	0.000	0.000	1.801	-0.085		13.408	-0.828	19.219	0.000	0.000	0.000	0.000
BEND_2		2532.583		26.451	1.530	19.963	0.000	0.000	1.348	-0.064		28.168	-1.593	19.270	0.000	0.000	0.000	0.000
BEND_1		2532.943		25.368	1.484	19.965	0.000	0.000	1.325	-0.064		29.329	-1.638	19.272	0.000	0.000	0.000	0.000
BEND_2		2539.039		11.965	0.715	20.022	0.000	0.000	0.999	-0.043		53.946	-2.400	19.296	0.000	0.000	0.000	0.000
SD		2539.962		10.753	0.598	20.035	0.000	0.000	0.959	-0.043		58.485	-2.515	19.299	0.000	0.000	0.000	0.000
Q113	D	2541.407		9.726	0.014	20.058	0.000	0.000	0.918	-0.004		63.176	0.004	19.302	0.000	0.000	0.000	0.000
BEND_1		2543.776		11.822	-0.681	20.094	0.000	0.000	0.980	0.035		53.909	2.407	19.309	0.000	0.000	0.000	0.000
BEND_2		2549.872		24.732	-1.436	20.152	0.000	0.000	1.256	0.056		29.233	1.640	19.333	0.000	0.000	0.000	0.000
BEND_1		2550.231		25.780	-1.481	20.154	0.000	0.000	1.276	0.056		28.070	1.595	19.335	0.000	0.000	0.000	0.000
BEND_2		2556.327		48.437	-2.236	20.181	0.000	0.000	1.679	0.077		13.307	0.826	19.386	0.000	0.000	0.000	0.000
SF		2557.251		52.673	-2.350	20.184	0.000	0.000	1.750	0.077		11.889	0.709	19.398	0.000	0.000	0.000	0.000
Q112	F	2558.696		57.103	-0.035	20.188	0.000	0.000	1.819	-0.001		10.592	0.080	19.419	0.000	0.000	0.000	0.000
BEND_1		2561.064		48.736	2.180	20.195	0.000	0.000	1.674	-0.079		12.480	-0.634	19.453	0.000	0.000	0.000	0.000
BEND_2		2567.160		26.543	1.461	20.223	0.000	0.000	1.257	-0.058		24.373	-1.317	19.509	0.000	0.000	0.000	0.000
BEND_1		2567.520		25.508	1.418	20.225	0.000	0.000	1.236	-0.058		25.334	-1.357	19.512	0.000	0.000	0.000	0.000
BEND_2		2573.616		12.605	0.699	20.280	0.000	0.000	0.946	-0.037		46.033	-2.038	19.540	0.000	0.000	0.000	0.000
SD		2574.539		11.416	0.590	20.292	0.000	0.000	0.912	-0.037		49.892	-2.141	19.543	0.000	0.000	0.000	0.000
Q111	D	2575.984		10.426	-0.012	20.314	0.000	0.000	0.878	0.000		53.892	0.001	19.548	0.000	0.000	0.000	0.000
BEND_1		2578.353		12.730	-0.727	20.347	0.000	0.000	0.946	0.037		46.026	2.039	19.555	0.000	0.000	0.000	0.000
BEND_2		2584.449		26.062	-1.460	20.401	0.000	0.000	1.238	0.058		25.317	1.358	19.584	0.000	0.000	0.000	0.000
BEND_1		2584.808		27.127	-1.503	20.404	0.000	0.000	1.259	0.058		24.356	1.317	19.586	0.000	0.000	0.000	0.000
BEND_2		2590.904		49.913	-2.235	20.430	0.000	0.000	1.677	0.079		12.462	0.633	19.643	0.000	0.000	0.000	0.000
SF		2591.828		54.144	-2.346	20.433	0.000	0.000	1.750	0.079		11.388	0.530	19.655	0.000	0.000	0.000	0.000
Q110	F	2593.273		58.489	0.035	20.437	0.000	0.000	1.823	0.001		10.576	-0.080	19.676	0.000	0.000	0.000	0.000
BEND_1		2595.641		49.609	2.292	20.444	0.000	0.000	1.683	-0.077		13.289	-0.826	19.709	0.000	0.000	0.000	0.000
BEND_2		2601.737		26.351	1.524	20.471	0.000	0.000	1.279	-0.056		28.051	-1.595	19.760	0.000	0.000	0.000	0.000
BEND_1		2602.097		25.272	1.478	20.473	0.000	0.000	1.259	-0.056		29.214	-1.641	19.762	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_2		2608.193		11.933	0.710	20.530	0.000	0.000	0.982	-0.035		53.897	-2.408	19.787	0.000	0.000	0.000	0.000
SD		2609.116		10.729	0.594	20.543	0.000	0.000	0.950	-0.035		58.452	-2.524	19.789	0.000	0.000	0.000	0.000
Q109	D	2610.561		9.714	0.010	20.566	0.000	0.000	0.920	0.004		63.170	-0.006	19.793	0.000	0.000	0.000	0.000
BEND_1		2612.930		11.827	-0.685	20.602	0.000	0.000	1.001	0.043		53.948	2.398	19.799	0.000	0.000	0.000	0.000
BEND_2		2619.026		24.802	-1.443	20.660	0.000	0.000	1.328	0.064		29.344	1.637	19.824	0.000	0.000	0.000	0.000
BEND_1		2619.385		25.855	-1.488	20.662	0.000	0.000	1.351	0.064		28.183	1.592	19.826	0.000	0.000	0.000	0.000
BEND_2		2625.481		48.610	-2.245	20.690	0.000	0.000	1.805	0.085		13.425	0.828	19.877	0.000	0.000	0.000	0.000
SF		2626.404		52.863	-2.360	20.693	0.000	0.000	1.883	0.085		12.002	0.712	19.888	0.000	0.000	0.000	0.000
Q108	F	2627.849		57.313	-0.036	20.697	0.000	0.000	1.961	0.001		10.699	0.079	19.909	0.000	0.000	0.000	0.000
BENDDS_1		2630.089		47.848	3.004	20.703	0.000	0.000	1.790	-0.114		12.821	-0.830	19.940	0.000	0.000	0.000	0.000
BENDDS_2		2634.153		26.891	2.153	20.721	0.000	0.000	1.354	-0.100		21.737	-1.364	19.979	0.000	0.000	0.000	0.000
BENDDS_1		2634.512		25.371	2.077	20.724	0.000	0.000	1.318	-0.100		22.734	-1.411	19.982	0.000	0.000	0.000	0.000
BENDDS_2		2638.576		11.947	1.226	20.761	0.000	0.000	0.940	-0.086		36.371	-1.944	20.004	0.000	0.000	0.000	0.000
Q107	D	2640.816		8.239	0.298	20.798	0.000	0.000	0.782	-0.038		42.092	0.283	20.013	0.000	0.000	0.000	0.000
BENDDS_1		2643.055		8.969	-0.468	20.841	0.000	0.000	0.764	0.006		34.108	2.369	20.023	0.000	0.000	0.000	0.000
BENDDS_2		2647.119		15.015	-1.020	20.898	0.000	0.000	0.817	0.020		18.052	1.582	20.049	0.000	0.000	0.000	0.000
BENDDS_1		2647.479		15.766	-1.069	20.902	0.000	0.000	0.825	0.020		16.940	1.512	20.052	0.000	0.000	0.000	0.000
BENDDS_2		2651.543		26.698	-1.621	20.934	0.000	0.000	0.935	0.034		7.852	0.724	20.109	0.000	0.000	0.000	0.000
Q106	F	2653.782		31.840	0.023	20.946	0.000	0.000	0.969	-0.024		6.116	-0.057	20.163	0.000	0.000	0.000	0.000
BENDDS_1		2656.022		26.514	1.656	20.958	0.000	0.000	0.831	-0.080		8.419	-0.869	20.215	0.000	0.000	0.000	0.000
BENDDS_2		2660.086		15.387	1.082	20.990	0.000	0.000	0.535	-0.066		18.921	-1.715	20.267	0.000	0.000	0.000	0.000
BENDDS_1		2660.445		14.628	1.031	20.994	0.000	0.000	0.512	-0.066		20.180	-1.790	20.270	0.000	0.000	0.000	0.000
BENDDS_2		2664.509		8.574	0.458	21.053	0.000	0.000	0.273	-0.052		38.163	-2.635	20.293	0.000	0.000	0.000	0.000
Q105	D	2666.749		7.884	-0.299	21.098	0.000	0.000	0.166	-0.040		46.989	-0.288	20.302	0.000	0.000	0.000	0.000
BENDDS_1		2668.988		11.562	-1.219	21.136	0.000	0.000	0.088	-0.032		40.463	2.203	20.310	0.000	0.000	0.000	0.000
BENDDS_2		2673.052		25.018	-2.092	21.175	0.000	0.000	-0.015	-0.018		24.937	1.616	20.330	0.000	0.000	0.000	0.000
BENDDS_1		2673.412		26.550	-2.170	21.177	0.000	0.000	-0.021	-0.018		23.794	1.564	20.332	0.000	0.000	0.000	0.000
BENDDS_2		2677.476		47.734	-3.043	21.195	0.000	0.000	-0.068	-0.004		13.468	0.976	20.369	0.000	0.000	0.000	0.000
Q104	F	2679.715		57.397	-0.010	21.202	0.000	0.000	-0.075	0.000		10.772	0.034	20.399	0.000	0.000	0.000	0.000
Q103	D	2697.004		10.172	-0.007	21.329	0.000	0.000	-0.023	0.002		56.533	0.015	20.523	0.000	0.000	0.000	0.000
Q102	F	2714.292		58.208	0.011	21.454	0.000	0.000	-0.002	0.001		10.449	-0.033	20.649	0.000	0.000	0.000	0.000
MI10		2714.292		58.208	0.011	21.454	0.000	0.000	-0.002	0.001		10.449	-0.033	20.649	0.000	0.000	0.000	0.000
Q101	D	2731.581		9.956	0.006	21.582	0.000	0.000	0.022	0.002		60.357	-0.018	20.770	0.000	0.000	0.000	0.000
Q100	F	2748.870		57.461	-0.011	21.710	0.000	0.000	0.075	0.000		10.822	0.031	20.888	0.000	0.000	0.000	0.000
BENDDS_1		2751.109		47.872	3.031	21.717	0.000	0.000	0.068	-0.004		13.198	-0.895	20.919	0.000	0.000	0.000	0.000
BENDDS_2		2755.173		26.753	2.166	21.735	0.000	0.000	0.079	0.010		22.723	-1.449	20.956	0.000	0.000	0.000	0.000
BENDDS_1		2755.533		25.223	2.090	21.737	0.000	0.000	0.082	0.010		23.782	-1.498	20.959	0.000	0.000	0.000	0.000
BENDDS_2		2759.597		11.753	1.225	21.775	0.000	0.000	0.149	0.023		38.200	-2.050	20.980	0.000	0.000	0.000	0.000
Q641	D	2761.836		8.051	0.301	21.813	0.000	0.000	0.209	0.034		44.233	0.295	20.989	0.000	0.000	0.000	0.000
BENDDS_1		2764.076		8.749	-0.460	21.857	0.000	0.000	0.306	0.048		35.841	2.492	20.998	0.000	0.000	0.000	0.000
BENDDS_2		2768.140		14.777	-1.023	21.915	0.000	0.000	0.530	0.062		18.902	1.675	21.023	0.000	0.000	0.000	0.000
BENDDS_1		2768.499		15.530	-1.073	21.919	0.000	0.000	0.553	0.062		17.724	1.603	21.026	0.000	0.000	0.000	0.000
BENDDS_2		2772.563		26.537	-1.636	21.951	0.000	0.000	0.833	0.076		8.019	0.785	21.081	0.000	0.000	0.000	0.000
Q640	F	2774.803		31.766	-0.002	21.963	0.000	0.000	0.963	0.020		6.045	-0.008	21.135	0.000	0.000	0.000	0.000
BENDDS_1		2777.042		26.552	1.633	21.975	0.000	0.000	0.922	-0.037		8.099	-0.805	21.188	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BENDDS_2		2781.106	15.560	1.072	22.007	0.000	0.000	0.799	-0.023	18.004	-1.632	21.242	0.000	0.000	0.000	0.000
BENDDS_1		2781.465	14.808	1.022	22.011	0.000	0.000	0.791	-0.023	19.203	-1.705	21.245	0.000	0.000	0.000	0.000
BENDDS_2		2785.529	8.781	0.461	22.069	0.000	0.000	0.725	-0.009	36.415	-2.530	21.270	0.000	0.000	0.000	0.000
Q639	D	2787.769	8.079	-0.301	22.113	0.000	0.000	0.735	0.033	44.926	-0.296	21.279	0.000	0.000	0.000	0.000
BENDDS_1		2790.008	11.784	-1.226	22.150	0.000	0.000	0.876	0.078	38.779	2.087	21.287	0.000	0.000	0.000	0.000
BENDDS_2		2794.072	25.251	-2.088	22.188	0.000	0.000	1.220	0.092	24.094	1.527	21.308	0.000	0.000	0.000	0.000
BENDDS_1		2794.432	26.780	-2.165	22.190	0.000	0.000	1.253	0.092	23.014	1.477	21.311	0.000	0.000	0.000	0.000
BENDDS_2		2798.496	47.881	-3.028	22.208	0.000	0.000	1.654	0.106	13.290	0.916	21.348	0.000	0.000	0.000	0.000
Q638	F	2800.735	57.454	0.015	22.215	0.000	0.000	1.812	-0.001	10.833	-0.015	21.379	0.000	0.000	0.000	0.000
BEND_1		2803.104	48.821	2.234	22.222	0.000	0.000	1.668	-0.078	13.239	-0.753	21.411	0.000	0.000	0.000	0.000
BEND_2		2809.200	26.146	1.486	22.249	0.000	0.000	1.254	-0.057	26.816	-1.473	21.463	0.000	0.000	0.000	0.000
BEND_1		2809.559	25.093	1.442	22.252	0.000	0.000	1.234	-0.057	27.890	-1.516	21.465	0.000	0.000	0.000	0.000
BEND_2		2815.655	12.074	0.694	22.309	0.000	0.000	0.947	-0.037	50.749	-2.233	21.491	0.000	0.000	0.000	0.000
SD		2816.579	10.897	0.581	22.321	0.000	0.000	0.913	-0.037	54.974	-2.342	21.494	0.000	0.000	0.000	0.000
Q637	D	2818.024	9.921	-0.007	22.344	0.000	0.000	0.881	0.001	59.323	0.023	21.498	0.000	0.000	0.000	0.000
BEND_1		2820.392	12.143	-0.710	22.379	0.000	0.000	0.951	0.038	50.549	2.271	21.505	0.000	0.000	0.000	0.000
BEND_2		2826.488	25.399	-1.465	22.435	0.000	0.000	1.247	0.059	27.375	1.530	21.531	0.000	0.000	0.000	0.000
BEND_1		2826.848	26.468	-1.509	22.438	0.000	0.000	1.269	0.059	26.291	1.486	21.533	0.000	0.000	0.000	0.000
BEND_2		2832.944	49.471	-2.264	22.465	0.000	0.000	1.692	0.080	12.700	0.743	21.587	0.000	0.000	0.000	0.000
SF		2833.867	53.759	-2.379	22.467	0.000	0.000	1.766	0.080	11.432	0.630	21.599	0.000	0.000	0.000	0.000
Q636	F	2835.312	58.220	-0.014	22.471	0.000	0.000	1.840	0.001	10.341	0.017	21.621	0.000	0.000	0.000	0.000
BEND_1		2837.681	49.595	2.241	22.478	0.000	0.000	1.698	-0.077	12.523	-0.702	21.655	0.000	0.000	0.000	0.000
BEND_2		2843.777	26.783	1.501	22.505	0.000	0.000	1.291	-0.056	25.503	-1.427	21.710	0.000	0.000	0.000	0.000
BEND_1		2844.136	25.720	1.457	22.507	0.000	0.000	1.271	-0.056	26.544	-1.470	21.712	0.000	0.000	0.000	0.000
BEND_2		2850.232	12.466	0.717	22.563	0.000	0.000	0.990	-0.036	48.871	-2.192	21.739	0.000	0.000	0.000	0.000
SD		2851.156	11.245	0.605	22.575	0.000	0.000	0.957	-0.036	53.021	-2.302	21.742	0.000	0.000	0.000	0.000
Q635	D	2852.601	10.210	0.007	22.597	0.000	0.000	0.927	0.004	57.344	-0.022	21.746	0.000	0.000	0.000	0.000
BEND_1		2854.969	12.390	-0.699	22.631	0.000	0.000	1.008	0.043	49.062	2.156	21.753	0.000	0.000	0.000	0.000
BEND_2		2861.065	25.380	-1.432	22.687	0.000	0.000	1.334	0.064	27.035	1.456	21.780	0.000	0.000	0.000	0.000
BEND_1		2861.425	26.425	-1.475	22.689	0.000	0.000	1.357	0.064	26.004	1.415	21.782	0.000	0.000	0.000	0.000
BEND_2		2867.521	48.872	-2.208	22.716	0.000	0.000	1.811	0.085	13.038	0.712	21.836	0.000	0.000	0.000	0.000
SF		2868.444	53.052	-2.319	22.719	0.000	0.000	1.889	0.085	11.822	0.605	21.848	0.000	0.000	0.000	0.000
Q634	F	2869.889	57.369	0.014	22.723	0.000	0.000	1.967	0.001	10.810	-0.018	21.869	0.000	0.000	0.000	0.000
BEND_1		2872.258	48.752	2.230	22.730	0.000	0.000	1.815	-0.083	13.229	-0.756	21.901	0.000	0.000	0.000	0.000
BEND_2		2878.354	26.118	1.483	22.758	0.000	0.000	1.371	-0.062	26.857	-1.479	21.953	0.000	0.000	0.000	0.000
BEND_1		2878.713	25.068	1.439	22.760	0.000	0.000	1.348	-0.062	27.936	-1.522	21.955	0.000	0.000	0.000	0.000
BEND_2		2884.809	12.075	0.692	22.817	0.000	0.000	1.032	-0.042	50.880	-2.241	21.981	0.000	0.000	0.000	0.000
SD		2885.732	10.901	0.579	22.830	0.000	0.000	0.993	-0.042	55.121	-2.351	21.984	0.000	0.000	0.000	0.000
Q633	D	2887.177	9.928	-0.008	22.852	0.000	0.000	0.955	-0.001	59.488	0.021	21.988	0.000	0.000	0.000	0.000
BEND_1		2889.546	12.159	-0.712	22.887	0.000	0.000	1.027	0.040	50.700	2.275	21.995	0.000	0.000	0.000	0.000
BEND_2		2895.642	25.441	-1.467	22.944	0.000	0.000	1.331	0.060	27.471	1.534	22.021	0.000	0.000	0.000	0.000
BEND_1		2896.001	26.511	-1.512	22.946	0.000	0.000	1.353	0.060	26.384	1.490	22.023	0.000	0.000	0.000	0.000
BEND_2		2902.097	49.545	-2.267	22.973	0.000	0.000	1.785	0.081	12.742	0.747	22.077	0.000	0.000	0.000	0.000
SF		2903.021	53.838	-2.381	22.976	0.000	0.000	1.860	0.081	11.466	0.634	22.089	0.000	0.000	0.000	0.000
Q632	F	2904.466	58.303	-0.014	22.980	0.000	0.000	1.933	-0.001	10.366	0.020	22.110	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			I	HORIZONTAL							I	VERTICAL						
element name	quad type	dist [m]	I	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	I	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
BEND_1		2906.834		49.662	2.245	22.986	0.000	0.000	1.778	-0.084		12.537	-0.699	22.144	0.000	0.000	0.000	0.000
BEND_2		2912.930		26.809	1.504	23.013	0.000	0.000	1.330	-0.063		25.467	-1.422	22.200	0.000	0.000	0.000	0.000
BEND_1		2913.290		25.744	1.460	23.015	0.000	0.000	1.307	-0.063		26.505	-1.464	22.202	0.000	0.000	0.000	0.000
BEND_2		2919.386		12.464	0.719	23.071	0.000	0.000	0.986	-0.042		48.748	-2.184	22.229	0.000	0.000	0.000	0.000
SD		2920.309		11.241	0.606	23.083	0.000	0.000	0.947	-0.042		52.882	-2.293	22.232	0.000	0.000	0.000	0.000
Q631	D	2921.754		10.202	0.009	23.105	0.000	0.000	0.907	-0.004		57.187	-0.020	22.236	0.000	0.000	0.000	0.000
BEND_1		2924.123		12.373	-0.697	23.139	0.000	0.000	0.969	0.035		48.918	2.152	22.243	0.000	0.000	0.000	0.000
BEND_2		2930.219		25.339	-1.430	23.195	0.000	0.000	1.244	0.056		26.941	1.452	22.270	0.000	0.000	0.000	0.000
BEND_1		2930.578		26.382	-1.473	23.197	0.000	0.000	1.264	0.056		25.913	1.411	22.272	0.000	0.000	0.000	0.000
BEND_2		2936.674		48.800	-2.205	23.225	0.000	0.000	1.667	0.076		12.994	0.708	22.326	0.000	0.000	0.000	0.000
SF		2937.598		52.976	-2.316	23.227	0.000	0.000	1.738	0.076		11.785	0.601	22.338	0.000	0.000	0.000	0.000
Q630	F	2939.043		57.289	0.013	23.232	0.000	0.000	1.807	-0.001		10.783	-0.021	22.359	0.000	0.000	0.000	0.000
BEND_1		2941.411		48.688	2.226	23.239	0.000	0.000	1.664	-0.078		13.213	-0.759	22.391	0.000	0.000	0.000	0.000
BEND_2		2947.507		26.094	1.480	23.266	0.000	0.000	1.252	-0.057		26.888	-1.484	22.443	0.000	0.000	0.000	0.000
BEND_1		2947.867		25.046	1.437	23.268	0.000	0.000	1.232	-0.057		27.970	-1.527	22.445	0.000	0.000	0.000	0.000
BEND_2		2953.963		12.078	0.691	23.325	0.000	0.000	0.947	-0.036		50.994	-2.249	22.471	0.000	0.000	0.000	0.000
SD		2954.886		10.906	0.578	23.338	0.000	0.000	0.914	-0.036		55.250	-2.359	22.474	0.000	0.000	0.000	0.000
Q629	D	2956.331		9.937	-0.009	23.360	0.000	0.000	0.882	0.001		59.636	0.018	22.478	0.000	0.000	0.000	0.000
BEND_1		2958.700		12.176	-0.714	23.395	0.000	0.000	0.953	0.039		50.836	2.279	22.485	0.000	0.000	0.000	0.000
BEND_2		2964.796		25.482	-1.469	23.452	0.000	0.000	1.252	0.059		27.563	1.538	22.511	0.000	0.000	0.000	0.000
BEND_1		2965.155		26.554	-1.514	23.454	0.000	0.000	1.273	0.059		26.473	1.494	22.513	0.000	0.000	0.000	0.000
BEND_2		2971.251		49.615	-2.269	23.481	0.000	0.000	1.699	0.080		12.786	0.751	22.567	0.000	0.000	0.000	0.000
SF		2972.175		53.912	-2.384	23.484	0.000	0.000	1.774	0.080		11.504	0.638	22.579	0.000	0.000	0.000	0.000
Q628	F	2973.620		58.380	-0.013	23.488	0.000	0.000	1.848	0.001		10.394	0.022	22.600	0.000	0.000	0.000	0.000
BEND_1		2975.988		49.723	2.249	23.495	0.000	0.000	1.706	-0.078		12.556	-0.697	22.634	0.000	0.000	0.000	0.000
BEND_2		2982.084		26.831	1.506	23.521	0.000	0.000	1.297	-0.057		25.443	-1.417	22.689	0.000	0.000	0.000	0.000
BEND_1		2982.443		25.764	1.463	23.523	0.000	0.000	1.277	-0.057		26.477	-1.459	22.691	0.000	0.000	0.000	0.000
BEND_2		2988.539		12.460	0.720	23.579	0.000	0.000	0.995	-0.036		48.643	-2.176	22.719	0.000	0.000	0.000	0.000
SD		2989.463		11.234	0.607	23.591	0.000	0.000	0.961	-0.036		52.763	-2.285	22.721	0.000	0.000	0.000	0.000
Q627	D	2990.908		10.192	0.010	23.613	0.000	0.000	0.931	0.004		57.050	-0.017	22.726	0.000	0.000	0.000	0.000
BEND_1		2993.276		12.356	-0.696	23.647	0.000	0.000	1.012	0.043		48.789	2.149	22.733	0.000	0.000	0.000	0.000
BEND_2		2999.372		25.298	-1.428	23.703	0.000	0.000	1.339	0.064		26.852	1.449	22.760	0.000	0.000	0.000	0.000
BEND_1		2999.732		26.340	-1.471	23.706	0.000	0.000	1.362	0.064		25.826	1.407	22.762	0.000	0.000	0.000	0.000
BEND_2		3005.828		48.733	-2.203	23.733	0.000	0.000	1.815	0.085		12.949	0.705	22.816	0.000	0.000	0.000	0.000
SF		3006.751		52.904	-2.314	23.736	0.000	0.000	1.894	0.085		11.746	0.598	22.828	0.000	0.000	0.000	0.000
Q626	F	3008.196		57.214	0.012	23.740	0.000	0.000	1.972	0.001		10.753	-0.023	22.849	0.000	0.000	0.000	0.000
BENDDS_1		3010.436		47.574	3.035	23.746	0.000	0.000	1.799	-0.115		13.392	-0.962	22.879	0.000	0.000	0.000	0.000
BENDDS_2		3014.500		26.454	2.163	23.765	0.000	0.000	1.359	-0.101		23.579	-1.545	22.916	0.000	0.000	0.000	0.000
BENDDS_1		3014.859		24.927	2.085	23.767	0.000	0.000	1.323	-0.101		24.708	-1.596	22.918	0.000	0.000	0.000	0.000
BENDDS_2		3018.923		11.522	1.213	23.805	0.000	0.000	0.940	-0.087		40.048	-2.178	22.939	0.000	0.000	0.000	0.000
Q625	D	3021.163		7.864	0.296	23.844	0.000	0.000	0.780	-0.039		46.497	0.287	22.947	0.000	0.000	0.000	0.000
BENDDS_1		3023.402		8.568	-0.461	23.889	0.000	0.000	0.759	0.005		37.758	2.607	22.955	0.000	0.000	0.000	0.000
BENDDS_2		3027.466		14.655	-1.037	23.948	0.000	0.000	0.807	0.019		19.972	1.769	22.979	0.000	0.000	0.000	0.000
BENDDS_1		3027.826		15.418	-1.087	23.952	0.000	0.000	0.814	0.019		18.727	1.695	22.982	0.000	0.000	0.000	0.000
BENDDS_2		3031.890		26.595	-1.663	23.984	0.000	0.000	0.919	0.033		8.365	0.855	23.034	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
Q624	F	3034.129	31.946	-0.025	23.996	0.000	0.000	0.950	-0.024	6.116	0.046	23.086	0.000	0.000	0.000	0.000
BENDDS_1		3036.369	26.792	1.626	24.008	0.000	0.000	0.814	-0.079	7.905	-0.737	23.140	0.000	0.000	0.000	0.000
BENDDS_2		3040.433	15.824	1.073	24.040	0.000	0.000	0.522	-0.065	17.119	-1.530	23.197	0.000	0.000	0.000	0.000
BENDDS_1		3040.792	15.070	1.024	24.043	0.000	0.000	0.498	-0.065	18.244	-1.600	23.200	0.000	0.000	0.000	0.000
BENDDS_2		3044.856	8.990	0.472	24.100	0.000	0.000	0.263	-0.051	34.467	-2.391	23.226	0.000	0.000	0.000	0.000
Q623	D	3047.096	8.244	-0.295	24.143	0.000	0.000	0.157	-0.040	42.523	-0.283	23.235	0.000	0.000	0.000	0.000
BENDDS_1		3049.335	11.933	-1.221	24.180	0.000	0.000	0.079	-0.032	36.728	1.968	23.244	0.000	0.000	0.000	0.000
BENDDS_2		3053.399	25.305	-2.069	24.218	0.000	0.000	-0.024	-0.019	22.920	1.430	23.266	0.000	0.000	0.000	0.000
BENDDS_1		3053.759	26.820	-2.144	24.220	0.000	0.000	-0.031	-0.019	21.910	1.382	23.269	0.000	0.000	0.000	0.000
BENDDS_2		3057.823	47.697	-2.993	24.238	0.000	0.000	-0.078	-0.005	12.868	0.843	23.308	0.000	0.000	0.000	0.000
Q622	F	3060.062	57.123	0.037	24.245	0.000	0.000	-0.084	0.000	10.694	-0.068	23.339	0.000	0.000	0.000	0.000
Q621	D	3077.351	9.700	-0.014	24.376	0.000	0.000	-0.018	0.003	62.587	0.002	23.456	0.000	0.000	0.000	0.000
MI62		3085.995	25.879	-1.508	24.470	0.000	0.000	0.003	0.002	28.439	1.598	23.488	0.000	0.000	0.000	0.000
Q620	F	3094.639	58.705	-0.037	24.505	0.000	0.000	0.023	0.001	10.641	0.069	23.572	0.000	0.000	0.000	0.000
Q619	D	3111.928	10.438	0.016	24.628	0.000	0.000	0.032	0.002	54.569	0.002	23.700	0.000	0.000	0.000	0.000
BENDDS_1		3114.167	12.794	-0.882	24.660	0.000	0.000	0.039	0.004	45.604	2.829	23.707	0.000	0.000	0.000	0.000
BENDDS_2		3118.231	22.255	-1.446	24.698	0.000	0.000	0.082	0.018	25.866	2.028	23.726	0.000	0.000	0.000	0.000
BENDDS_1		3118.591	23.312	-1.496	24.701	0.000	0.000	0.088	0.018	24.434	1.957	23.728	0.000	0.000	0.000	0.000
BENDDS_2		3122.655	37.768	-2.061	24.723	0.000	0.000	0.188	0.031	11.791	1.154	23.766	0.000	0.000	0.000	0.000
Q618	F	3124.894	43.815	0.312	24.731	0.000	0.000	0.249	0.018	8.369	0.235	23.803	0.000	0.000	0.000	0.000
BENDDS_1		3127.134	35.284	2.524	24.740	0.000	0.000	0.265	0.002	9.439	-0.554	23.845	0.000	0.000	0.000	0.000
BENDDS_2		3131.198	18.217	1.675	24.766	0.000	0.000	0.303	0.016	16.225	-1.116	23.898	0.000	0.000	0.000	0.000
BENDDS_1		3131.557	17.039	1.600	24.769	0.000	0.000	0.309	0.016	17.044	-1.165	23.902	0.000	0.000	0.000	0.000
BENDDS_2		3135.621	7.485	0.751	24.828	0.000	0.000	0.403	0.030	28.798	-1.726	23.931	0.000	0.000	0.000	0.000
Q617	D	3137.861	5.653	-0.029	24.885	0.000	0.000	0.489	0.057	34.274	0.016	23.942	0.000	0.000	0.000	0.000
BENDDS_1		3140.100	7.773	-0.825	24.941	0.000	0.000	0.662	0.088	28.669	1.751	23.953	0.000	0.000	0.000	0.000
BENDDS_2		3144.164	18.044	-1.703	24.997	0.000	0.000	1.048	0.102	16.777	1.175	23.983	0.000	0.000	0.000	0.000
BENDDS_1		3144.524	19.296	-1.780	25.000	0.000	0.000	1.085	0.102	15.951	1.124	23.986	0.000	0.000	0.000	0.000
BENDDS_2		3148.588	37.336	-2.659	25.024	0.000	0.000	1.527	0.116	9.156	0.548	24.041	0.000	0.000	0.000	0.000
Q616	F	3150.827	46.286	-0.311	25.032	0.000	0.000	1.714	0.016	8.107	-0.234	24.084	0.000	0.000	0.000	0.000
BENDDS_1		3153.067	39.809	2.197	25.041	0.000	0.000	1.597	-0.085	11.494	-1.145	24.122	0.000	0.000	0.000	0.000
BENDDS_2		3157.131	24.371	1.602	25.061	0.000	0.000	1.278	-0.072	24.115	-1.961	24.161	0.000	0.000	0.000	0.000
BENDDS_1		3157.490	23.239	1.549	25.064	0.000	0.000	1.252	-0.072	25.551	-2.033	24.164	0.000	0.000	0.000	0.000
BENDDS_2		3161.554	13.062	0.955	25.101	0.000	0.000	0.990	-0.058	45.384	-2.847	24.183	0.000	0.000	0.000	0.000
Q615	D	3163.794	10.419	0.042	25.133	0.000	0.000	0.901	-0.004	54.458	-0.035	24.190	0.000	0.000	0.000	0.000
BEND_1		3166.162	12.442	-0.662	25.167	0.000	0.000	0.961	0.034	46.661	2.033	24.197	0.000	0.000	0.000	0.000
BEND_2		3172.258	24.814	-1.367	25.223	0.000	0.000	1.231	0.055	25.951	1.364	24.225	0.000	0.000	0.000	0.000
BEND_1		3172.618	25.812	-1.409	25.225	0.000	0.000	1.251	0.055	24.985	1.324	24.227	0.000	0.000	0.000	0.000
BEND_2		3178.714	47.285	-2.114	25.253	0.000	0.000	1.649	0.076	12.927	0.653	24.282	0.000	0.000	0.000	0.000
SF		3179.637	51.288	-2.221	25.256	0.000	0.000	1.719	0.076	11.815	0.551	24.294	0.000	0.000	0.000	0.000
Q614	F	3181.082	55.402	0.033	25.260	0.000	0.000	1.787	-0.001	10.952	-0.071	24.315	0.000	0.000	0.000	0.000
BEND_1		3183.451	47.005	2.166	25.268	0.000	0.000	1.645	-0.077	13.663	-0.824	24.346	0.000	0.000	0.000	0.000
BEND_2		3189.547	25.098	1.428	25.296	0.000	0.000	1.239	-0.056	28.275	-1.572	24.397	0.000	0.000	0.000	0.000
BEND_1		3189.906	24.088	1.384	25.298	0.000	0.000	1.219	-0.056	29.421	-1.616	24.399	0.000	0.000	0.000	0.000
BEND_2		3196.002	11.709	0.646	25.358	0.000	0.000	0.940	-0.035	53.671	-2.361	24.423	0.000	0.000	0.000	0.000

Linear lattice functions for beam line: MI17
delta(p)/p = 0.000000 symm = F

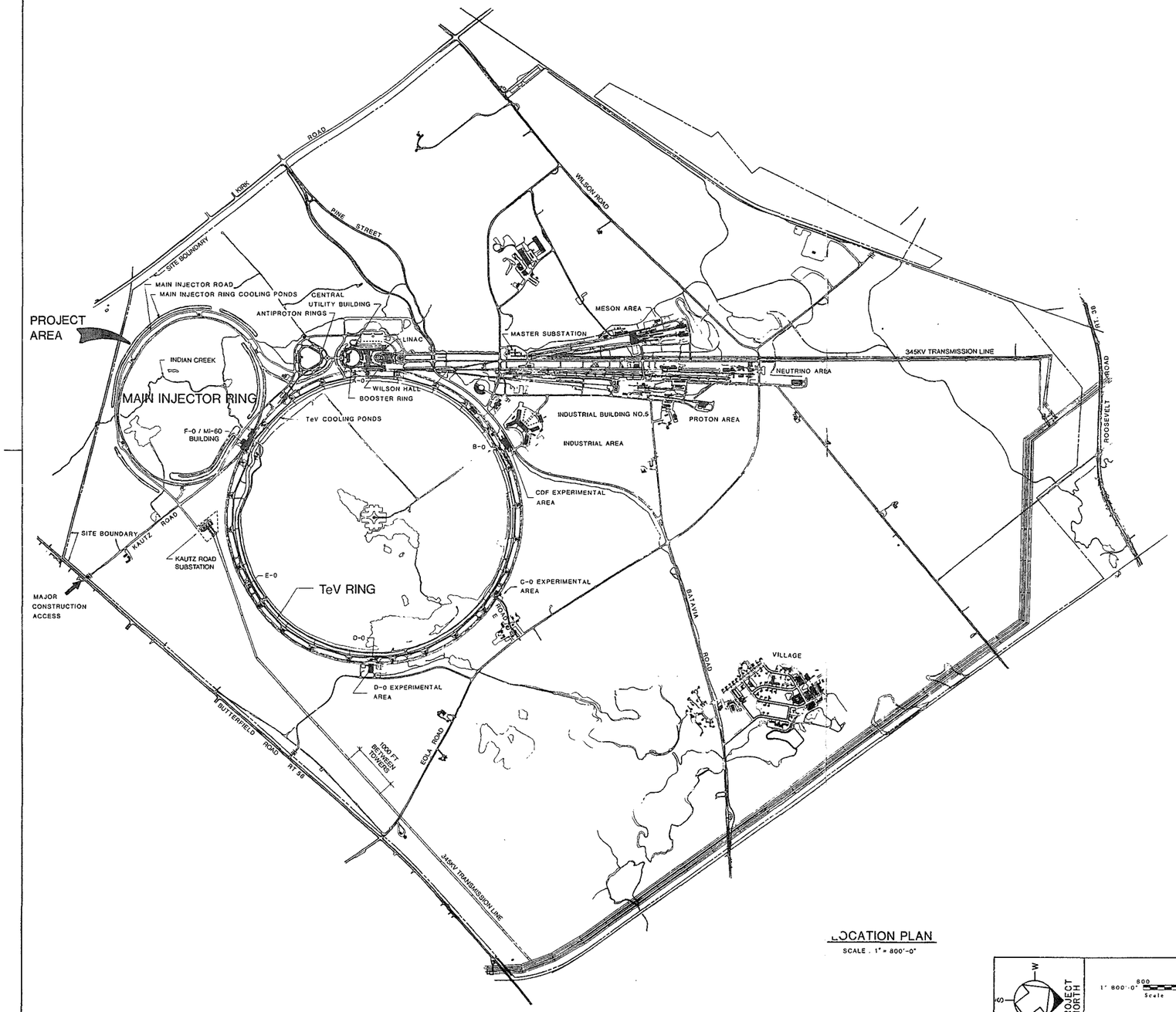
ELEMENT SEQUENCE			HORIZONTAL							VERTICAL						
element name	quad type	dist [m]	betax [m]	alfax [1]	mux [2pi]	x(co) [mm]	px(co) [.001]	Dx [m]	Dpx [1]	betay [m]	alfay [1]	muy [2pi]	y(co) [mm]	py(co) [.001]	Dy [m]	Dpy [1]
SD		3196.925	10.618	0.535	25.371	0.000	0.000	0.908	-0.035	58.136	-2.474	24.426	0.000	0.000	0.000	0.000
Q613	D	3198.370	9.764	-0.044	25.394	0.000	0.000	0.877	0.002	62.722	0.030	24.429	0.000	0.000	0.000	0.000
BENDDS_1		3200.610	12.328	-0.930	25.427	0.000	0.000	0.958	0.054	52.284	3.282	24.436	0.000	0.000	0.000	0.000
BENDDS_2		3204.674	22.386	-1.545	25.467	0.000	0.000	1.205	0.068	29.316	2.369	24.452	0.000	0.000	0.000	0.000
BENDDS_1		3205.033	23.516	-1.599	25.469	0.000	0.000	1.229	0.068	27.643	2.287	24.454	0.000	0.000	0.000	0.000
BENDDS_2		3209.097	39.015	-2.214	25.490	0.000	0.000	1.533	0.082	12.770	1.372	24.489	0.000	0.000	0.000	0.000
Q612	F	3211.337	45.656	0.243	25.499	0.000	0.000	1.644	-0.016	8.540	0.381	24.524	0.000	0.000	0.000	0.000
BENDDS_1		3213.576	37.078	2.576	25.507	0.000	0.000	1.464	-0.111	8.952	-0.397	24.566	0.000	0.000	0.000	0.000
BENDDS_2		3217.640	19.543	1.739	25.531	0.000	0.000	1.040	-0.098	14.316	-0.922	24.625	0.000	0.000	0.000	0.000
BENDDS_1		3218.000	18.320	1.665	25.534	0.000	0.000	1.005	-0.098	14.995	-0.969	24.629	0.000	0.000	0.000	0.000
BENDDS_2		3222.064	8.188	0.828	25.588	0.000	0.000	0.636	-0.084	25.001	-1.493	24.662	0.000	0.000	0.000	0.000
Q611	D	3224.303	6.033	0.033	25.641	0.000	0.000	0.472	-0.053	29.774	0.000	24.675	0.000	0.000	0.000	0.000
BENDDS_1		3226.543	7.854	-0.743	25.695	0.000	0.000	0.391	-0.028	25.000	1.493	24.688	0.000	0.000	0.000	0.000
BENDDS_2		3230.607	17.157	-1.546	25.752	0.000	0.000	0.306	-0.014	14.994	0.969	24.722	0.000	0.000	0.000	0.000
BENDDS_1		3230.966	18.294	-1.617	25.755	0.000	0.000	0.301	-0.014	14.314	0.922	24.725	0.000	0.000	0.000	0.000
BENDDS_2		3235.030	34.703	-2.420	25.781	0.000	0.000	0.273	0.000	8.951	0.397	24.784	0.000	0.000	0.000	0.000
Q610	F	3237.270	42.795	-0.245	25.790	0.000	0.000	0.261	-0.016	8.539	-0.381	24.826	0.000	0.000	0.000	0.000
BENDDS_1		3239.509	36.651	2.057	25.799	0.000	0.000	0.203	-0.031	12.768	-1.372	24.861	0.000	0.000	0.000	0.000
BENDDS_2		3243.573	22.291	1.477	25.822	0.000	0.000	0.106	-0.017	27.641	-2.288	24.896	0.000	0.000	0.000	0.000
BENDDS_1		3243.933	21.247	1.426	25.824	0.000	0.000	0.100	-0.017	29.314	-2.369	24.898	0.000	0.000	0.000	0.000
BENDDS_2		3247.997	12.018	0.846	25.865	0.000	0.000	0.061	-0.003	52.283	-3.283	24.915	0.000	0.000	0.000	0.000
Q609	D	3250.236	9.786	-0.023	25.899	0.000	0.000	0.057	0.000	62.721	-0.030	24.921	0.000	0.000	0.000	0.000
Q608	F	3267.525	59.224	-0.028	26.026	0.000	0.000	0.102	-0.002	10.996	0.069	25.035	0.000	0.000	0.000	0.000
Q607	D	3284.813	10.345	0.024	26.149	0.000	0.000	0.003	-0.006	54.642	0.035	25.160	0.000	0.000	0.000	0.000
Q606	F	3302.102	56.399	0.027	26.276	0.000	0.000	-0.092	-0.002	10.246	-0.067	25.290	0.000	0.000	0.000	0.000
Q605	D	3319.391	9.811	-0.026	26.407	0.000	0.000	-0.057	0.000	62.422	-0.040	25.410	0.000	0.000	0.000	0.000
MI60		3319.391	9.811	-0.026	0.000	0.000	0.000	-0.057	0.000	62.422	-0.040	0.000	0.000	0.000	0.000	0.000

otal length =	3319.390646	mux =	26.407483	muy =	25.410007
elta(s) =	0.000000 mm	dmux =	-2.417258	dmuy =	-2.238283
		betax(max) =	59.866430	betay(max) =	63.176026
		Dx(max) =	1.978201	Dy(max) =	0.000000
		Dx(r.m.s.) =	1.190819	Dy(r.m.s.) =	0.000000

APPENDIX E

CIVIL CONSTRUCTION DRAWINGS

FERMILAB MAIN INJECTOR



LOCATION PLAN

SCALE . 1" = 800'-0"

LIST OF DRAWINGS

	CDR-1	LOCATION PLAN
	CDR-2	AERIAL PERSPECTIVE
	CDR-3	EXISTING CONDITIONS
	CDR-4	MITIGATION PLAN
*	CDR-5	SITE PLAN
*	CDR-6	SITE CRITERIA PLAN
*	CDR-7	UTILITY PLAN
	CDR-8	EXCAVATION SECTIONS
	CDR-9	MITIGATION AREA PLAN AND PROFILES
	CDR-10	BEAMLINE GEOMETRICS
*	CDR-11	ENCLOSURE CRITERIA PLAN
*	CDR-12	F-0 / MI-60 ENCLOSURE PLAN
	CDR-13	MAIN INJECTOR ABORT PLAN AND SECTION
*	CDR-14	P-150 GEV ENCLOSURE LONG. SECTION
*	CDR-15	A-150 GEV ENCLOSURE LONG. SECTION
*	CDR-16	INJECTOR ENCLOSURE SECTIONS
	CDR-17	PRECAST ENCLOSURE DETAILS
	CDR-18	8 GEV BEAMLINE SHT. 1
*	CDR-19	8 GEV BEAMLINE SHT. 2
*	CDR-20	8 GEV BEAMLINE SHT. 3
*	CDR-21	8 GEV BEAMLINE SHT. 4
*	CDR-22	8 GEV BEAMLINE SHT. 5
*	CDR-23	8 GEV BEAMLINE SHT. 6
	CDR-24	8 GEV SECTION SHT. 1
	CDR-25	8 GEV SECTIONS SHT. 2
	CDR-26	TYPICAL SERVICE BUILDING PLAN
	CDR-27	ALCOVE PLANS
	CDR-28	SERVICE BUILDING SECTION
*	CDR-29	KICKER SERVICE BUILDING
*	CDR-30	F-0 / MI-60 PLAN
*	CDR-31	MI-60 CONSTRUCTION SECTIONS
*	CDR-32	MI-60 BUILDING SECTIONS
	CDR-33	NORTH HATCH BUILDING PLAN
	CDR-34	NORTH HATCH BLDG. SECTIONS
*	CDR-35	INDUSTRIAL BUILDING NO. 5
	CDR-36	HVAC & FIRE PROTECTION CRITERIA
	CDR-37	HVAC PLANS
	CDR-38	PROCESS SYSTEM - CRITERIA
	CDR-39	PROCESS SYSTEMS - FLOW DIAGRAM
	CDR-40	345-13.8KV SINGLE LINE DIAGRAM
	CDR-41	SINGLE LINE POWER DISTRIBUTION
	CDR-42	POWER & COMMUNICATION DUCT PLAN
	CDR-43	ELECTRICAL CRITERIA

* INDICATES DRAWINGS SUBJECT TO MODIFICATIONS FOR TITLE I INCORPORATING CHANGES IN 8 GEV AND 150 GEV ENCLOSURES, TRANSFERRING KICKER FUNCTION FROM MI60 TO NEW F17 KICKER BUILDING AND ELIMINATING IB #5

REV	DATE	DESCRIPTIONS
		REVISIONS
DESIGNED		C. FEDEROWICZ
DRAWN		C. FEDEROWICZ / L. JENKINS
CHECKED		
APPROVED		
SUBMITTED		

W S E N PROJECT NORTH

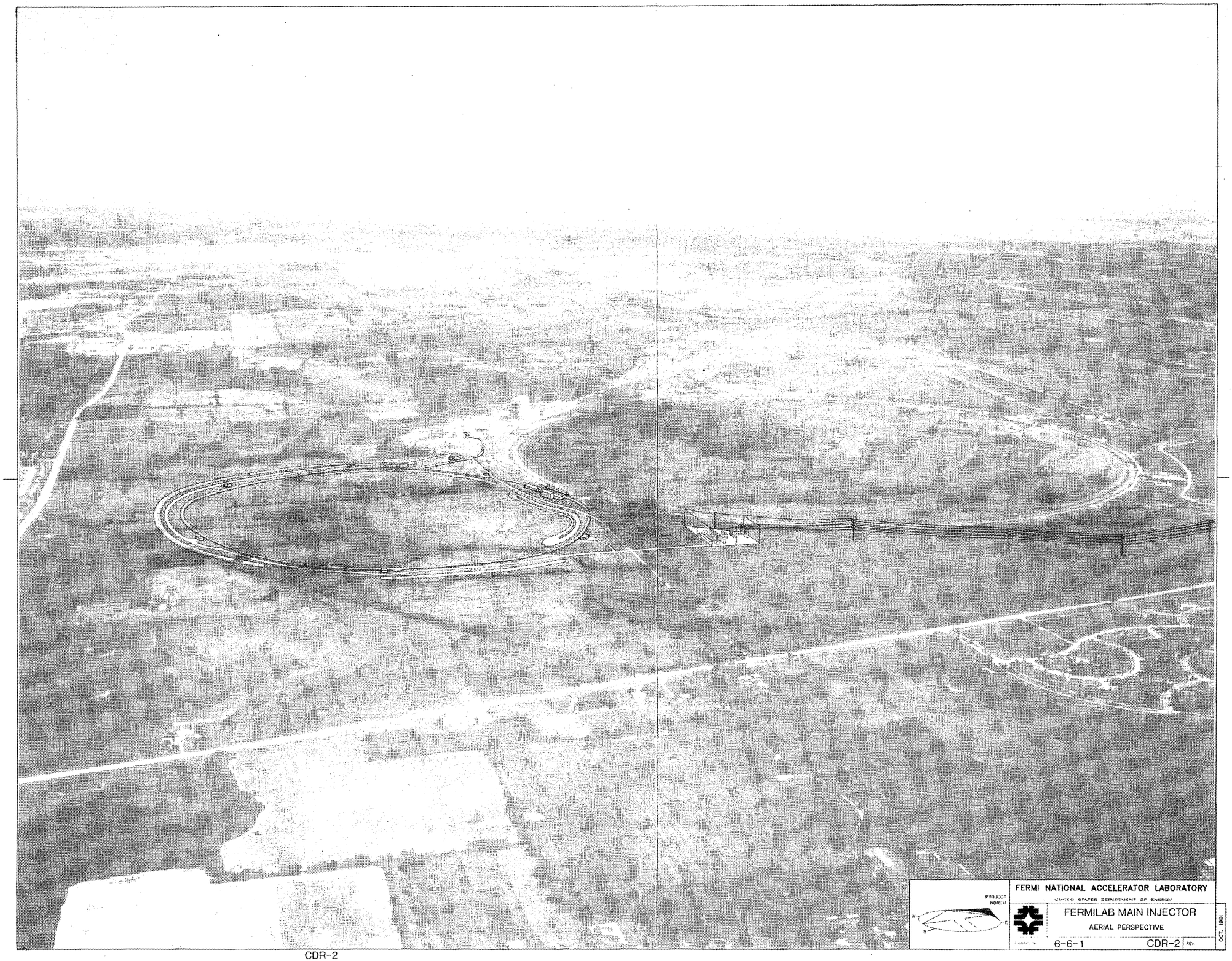
1" 800'-0" 800 0 800 1600 Scale Feet

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

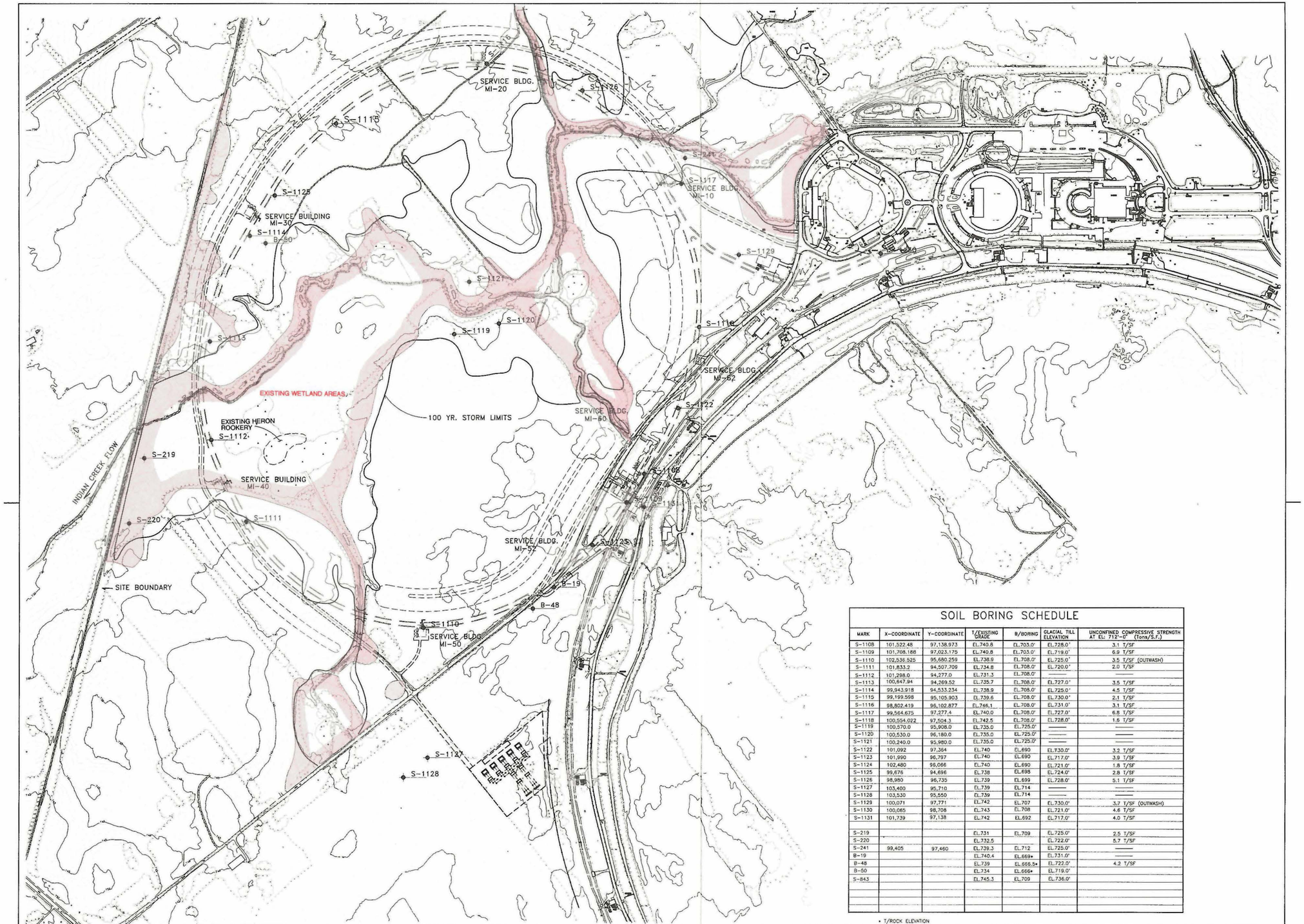
FERMILAB MAIN INJECTOR
LOCATION PLAN

DRAWING NO 6-6-1 CDR-1 REV.

OCT. 1991


PROJECT NORTH
W
E
S
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
FERMILAB MAIN INJECTOR
AERIAL PERSPECTIVE
6-6-1
CDR-2
REV.
OCT. 1988

CDR-2



SOIL BORING SCHEDULE

MARK	X-COORDINATE	Y-COORDINATE	T/EXISTING GRADE	B/BORING	GLACIAL TILL ELEVATION	UNCONFINED COMPRESSIVE STRENGTH AT EL. 712'-0" (Tons/S.F.)
S-1108	101,522.48	97,138.973	EL.740.8	EL.703.0'	EL.728.0'	3.1 T/SF
S-1109	101,708.168	97,023.175	EL.740.8	EL.703.0'	EL.719.0'	6.9 T/SF
S-1110	102,536.525	95,680.259	EL.738.9	EL.708.0'	EL.725.0'	3.5 T/SF (OUTWASH)
S-1111	101,833.2	94,507.709	EL.734.8	EL.708.0'	EL.720.0'	2.0 T/SF
S-1112	101,298.0	94,277.0	EL.731.3	EL.708.0'	———	———
S-1113	100,647.94	94,269.52	EL.735.7	EL.708.0'	EL.727.0'	3.5 T/SF
S-1114	99,943.918	94,533.234	EL.738.9	EL.708.0'	EL.725.0'	4.5 T/SF
S-1115	99,199.598	95,105.903	EL.739.6	EL.708.0'	EL.730.0'	2.1 T/SF
S-1116	98,802.419	96,102.877	EL.746.1	EL.708.0'	EL.731.0'	3.1 T/SF
S-1117	99,564.675	97,277.4	EL.740.0	EL.708.0'	EL.727.0'	6.8 T/SF
S-1118	100,554.022	97,504.3	EL.742.5	EL.708.0'	EL.728.0'	1.6 T/SF
S-1119	100,570.0	95,908.0	EL.735.0	EL.725.0'	———	———
S-1120	100,530.0	96,180.0	EL.735.0	EL.725.0'	———	———
S-1121	100,240.0	95,980.0	EL.735.0	EL.725.0'	———	———
S-1122	101,092	97,364	EL.740	EL.690	EL.730.0'	3.2 T/SF
S-1123	101,990	96,797	EL.740	EL.690	EL.717.0'	3.9 T/SF
S-1124	102,480	96,066	EL.740	EL.690	EL.721.0'	1.8 T/SF
S-1125	99,676	94,696	EL.738	EL.698	EL.724.0'	2.8 T/SF
S-1126	98,980	96,735	EL.739	EL.699	EL.728.0'	5.1 T/SF
S-1127	103,400	95,710	EL.739	EL.714	———	———
S-1128	103,530	95,550	EL.739	EL.714	———	———
S-1129	100,071	97,771	EL.742	EL.707	EL.730.0'	3.7 T/SF (OUTWASH)
S-1130	100,065	98,708	EL.743	EL.708	EL.721.0'	4.6 T/SF
S-1131	101,739	97,138	EL.742	EL.692	EL.717.0'	4.0 T/SF
S-219			EL.731	EL.709	EL.725.0'	2.5 T/SF
S-220			EL.732.5		EL.722.0'	5.7 T/SF
S-241	99,405	97,460	EL.739.3	EL.712	EL.725.0'	———
B-19			EL.740.4	EL.669*	EL.731.0'	———
B-48			EL.739	EL.666.5*	EL.722.0'	4.2 T/SF
B-50			EL.734	EL.666*	EL.719.0'	
S-843			EL.745.3	EL.709	EL.736.0'	

* T/ROCK ELEVATION

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	C. FEDEROWICZ	
DRAWN	C. FEDEROWICZ	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 200'-0" (200 0 200 400 SCALE FEET)

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
EXISTING CONDITIONS

DRAWING NO. 6-6-1 CDR-3 REV.

OCT. 1991

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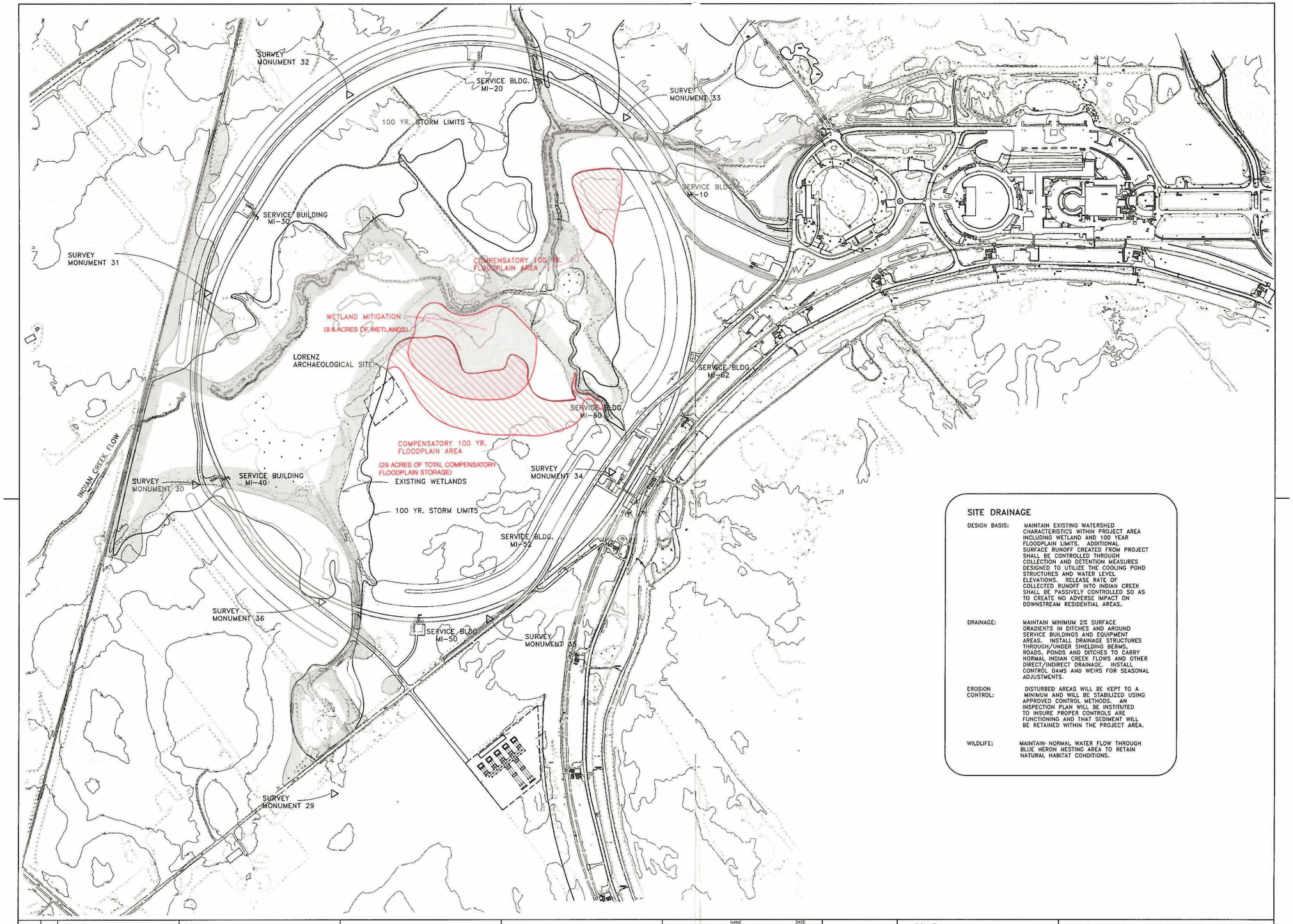

SITE DRAINAGE

DESIGN BASIS: MAINTAIN EXISTING WATERSHED CHARACTERISTICS WITHIN PROJECT AREA INCLUDING WETLAND AND 100 YEAR FLOODPLAIN LIMITS. ADDITIONAL SURFACE RUNOFF CREATED FROM PROJECT SHALL BE CONTROLLED THROUGH COLLECTION AND DETENTION MEASURES DESIGNED TO UTILIZE THE COOLING POND STRUCTURES AND WATER LEVEL ELEVATIONS. RELEASE RATE OF COLLECTED RUNOFF INTO INDIAN CREEK SHALL BE PASSIVELY CONTROLLED SO AS TO CREATE NO ADVERSE IMPACT ON DOWNSTREAM RESIDENTIAL AREAS.

DRAINAGE: MAINTAIN MINIMUM 2% SURFACE GRADIENTS IN DITCHES AND AROUND SERVICE BUILDINGS AND EQUIPMENT AREAS. INSTALL DRAINAGE STRUCTURES THROUGH/UNDER SHIELDING BERMS, ROADS, PONDS AND DITCHES TO CARRY NORMAL INDIAN CREEK FLOWS AND OTHER DIRECT/INDIRECT DRAINAGE. INSTALL CONTROL DAMS AND WEIRS FOR SEASONAL ADJUSTMENTS.

EROSION CONTROL: DISTURBED AREAS WILL BE KEPT TO A MINIMUM AND WILL BE STABILIZED USING APPROVED CONTROL METHODS. AN INSPECTION PLAN WILL BE INSTITUTED TO INSURE PROPER CONTROLS ARE FUNCTIONING AND THAT SEDIMENT WILL BE RETAINED WITHIN THE PROJECT AREA.

WILDLIFE: MAINTAIN NORMAL WATER FLOW THROUGH BLUE HERON NESTING AREA TO RETAIN NATURAL HABITAT CONDITIONS.

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	C. FEDEROWICZ	
DRAWN	C. FEDEROWICZ	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 200'-0" 200 0 200 400 SCALE FEET

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
MITIGATION PLAN

DRAWING NO. 6-6-1 CDR-4 REV.

OCT. 1991

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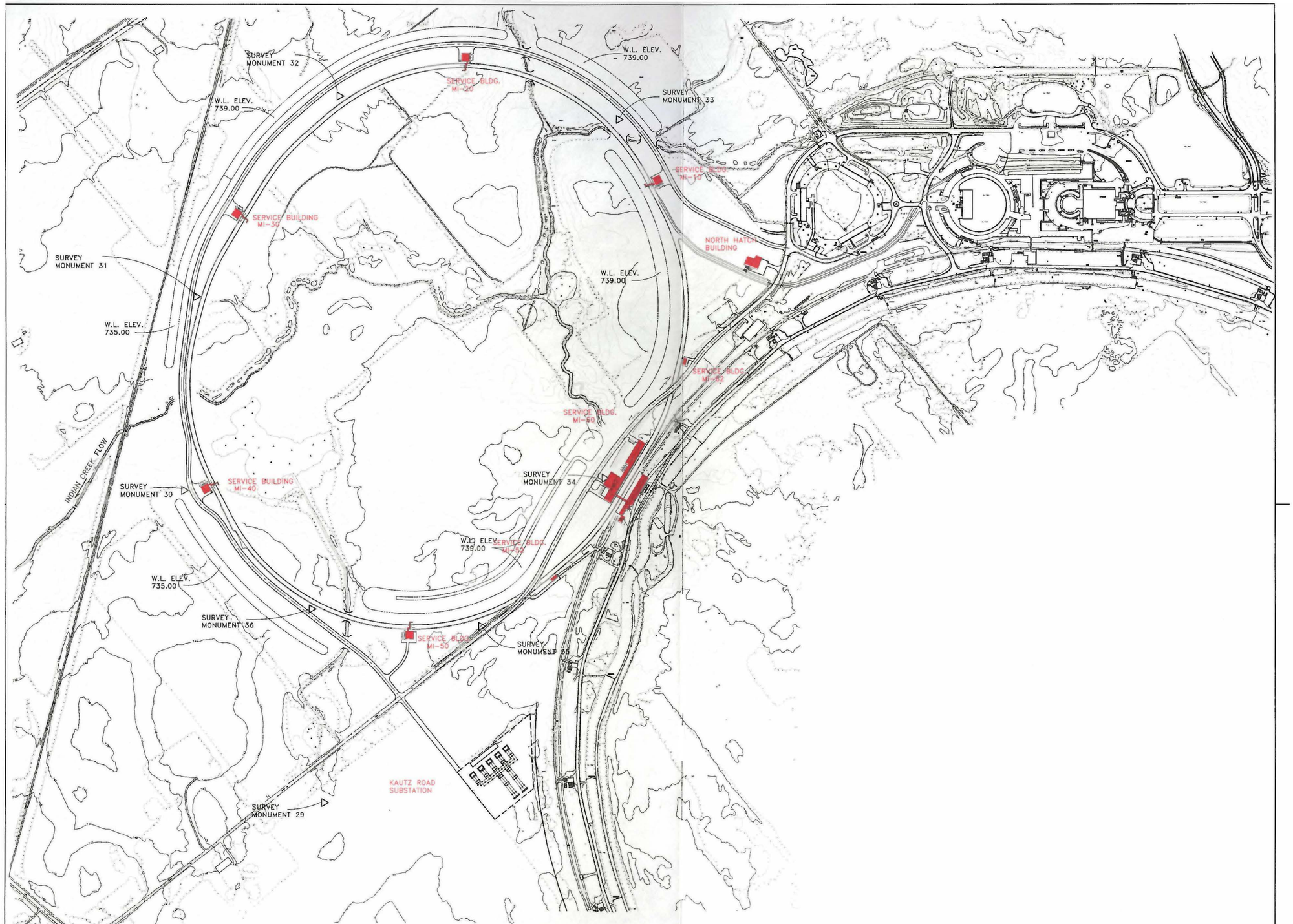


REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	C. FEDEROWICZ	
DRAWN	C. FEDEROWICZ	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 200'-0" (200 0 200 400 SCALE FEET)

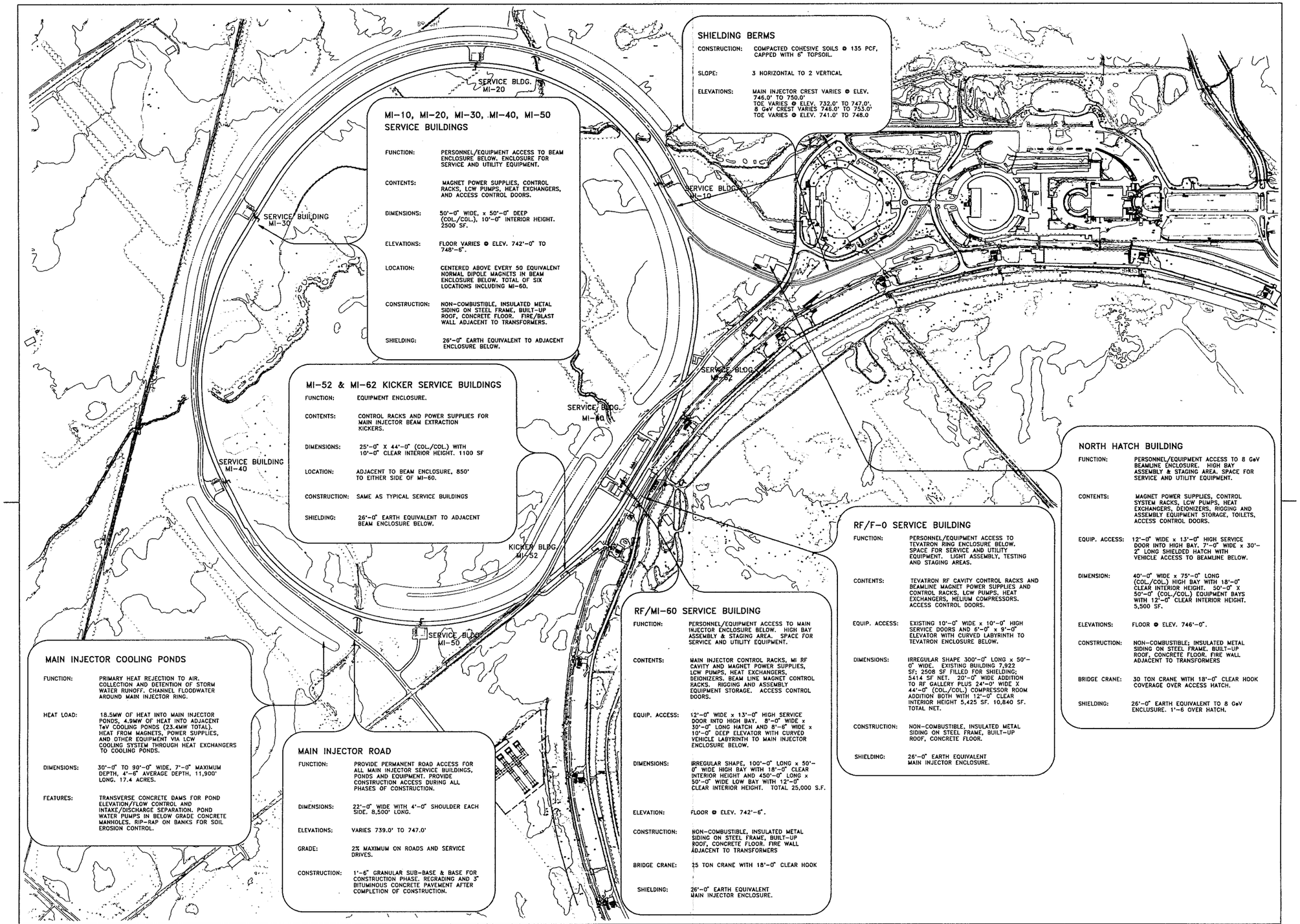
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
SITE PLAN

DRAWING NO. 6-6-1 CDR-5 REV.

OCT. 1991

09:17:22p.m. 23OCT91



SHIELDING BERMS

CONSTRUCTION: COMPACTED COHESIVE SOILS @ 135 PCF, CAPPED WITH 6" TOPSOIL.

SLOPE: 3 HORIZONTAL TO 2 VERTICAL

ELEVATIONS: MAIN INJECTOR CREST VARIES @ ELEV. 746.0' TO 750.0'
TOE VARIES @ ELEV. 732.0' TO 747.0'.
8 GeV CREST VARIES 746.0' TO 753.0'
TOE VARIES @ ELEV. 741.0' TO 748.0

MI-10, MI-20, MI-30, MI-40, MI-50 SERVICE BUILDINGS

FUNCTION: PERSONNEL/EQUIPMENT ACCESS TO BEAM ENCLOSURE BELOW. ENCLOSURE FOR SERVICE AND UTILITY EQUIPMENT.

CONTENTS: MAGNET POWER SUPPLIES, CONTROL RACKS, LCW PUMPS, HEAT EXCHANGERS, AND ACCESS CONTROL DOORS.

DIMENSIONS: 50'-0" WIDE, x 50'-0" DEEP (COL./COL.), 10'-0" INTERIOR HEIGHT. 2500 SF.

ELEVATIONS: FLOOR VARIES @ ELEV. 742'-0" TO 748'-6".

LOCATION: CENTERED ABOVE EVERY 50 EQUIVALENT NORMAL DIPOLE MAGNETS IN BEAM ENCLOSURE BELOW. TOTAL OF SIX LOCATIONS INCLUDING MI-60.

CONSTRUCTION: NON-COMBUSTIBLE, INSULATED METAL SIDING ON STEEL FRAME, BUILT-UP ROOF, CONCRETE FLOOR. FIRE/BLAST WALL ADJACENT TO TRANSFORMERS.

SHIELDING: 26'-0" EARTH EQUIVALENT TO ADJACENT ENCLOSURE BELOW.

MI-52 & MI-62 KICKER SERVICE BUILDINGS

FUNCTION: EQUIPMENT ENCLOSURE.

CONTENTS: CONTROL RACKS AND POWER SUPPLIES FOR MAIN INJECTOR BEAM EXTRACTION KICKERS.

DIMENSIONS: 25'-0" X 44'-0" (COL./COL.) WITH 10'-0" CLEAR INTERIOR HEIGHT. 1100 SF

LOCATION: ADJACENT TO BEAM ENCLOSURE, 850' TO EITHER SIDE OF MI-60.

CONSTRUCTION: SAME AS TYPICAL SERVICE BUILDINGS

SHIELDING: 26'-0" EARTH EQUIVALENT TO ADJACENT BEAM ENCLOSURE BELOW.

NORTH HATCH BUILDING

FUNCTION: PERSONNEL/EQUIPMENT ACCESS TO 8 GeV BEAMLINE ENCLOSURE. HIGH BAY ASSEMBLY & STAGING AREA. SPACE FOR SERVICE AND UTILITY EQUIPMENT.

CONTENTS: MAGNET POWER SUPPLIES, CONTROL SYSTEM RACKS, LCW PUMPS, HEAT EXCHANGERS, DEIONIZERS, RIGGING AND ASSEMBLY EQUIPMENT STORAGE, TOILETS, ACCESS CONTROL DOORS.

EQUIP. ACCESS: 12'-0" WIDE x 13'-0" HIGH SERVICE DOOR INTO HIGH BAY. 7'-0" WIDE x 30'-2" LONG SHIELDED HATCH WITH VEHICLE ACCESS TO BEAMLINE BELOW.

DIMENSION: 40'-0" WIDE x 75'-0" LONG (COL./COL.) HIGH BAY WITH 18'-0" CLEAR INTERIOR HEIGHT. 50'-0" X 50'-0" (COL./COL.) EQUIPMENT BAYS WITH 12'-0" CLEAR INTERIOR HEIGHT. 5,500 SF.

ELEVATIONS: FLOOR @ ELEV. 746'-0".

CONSTRUCTION: NON-COMBUSTIBLE; INSULATED METAL SIDING ON STEEL FRAME. BUILT-UP ROOF. CONCRETE FLOOR. FIRE WALL ADJACENT TO TRANSFORMERS

BRIDGE CRANE: 30 TON CRANE WITH 18'-0" CLEAR HOOK COVERAGE OVER ACCESS HATCH.

SHIELDING: 26'-0" EARTH EQUIVALENT TO 8 GeV ENCLOSURE. 1'-6 OVER HATCH.

RF/F-0 SERVICE BUILDING

FUNCTION: PERSONNEL/EQUIPMENT ACCESS TO TEVATRON RING ENCLOSURE BELOW. SPACE FOR SERVICE AND UTILITY EQUIPMENT. LIGHT ASSEMBLY, TESTING AND STAGING AREAS.

CONTENTS: TEVATRON RF CAVITY CONTROL RACKS AND BEAMLINE MAGNET POWER SUPPLIES AND CONTROL RACKS, LCW PUMPS, HEAT EXCHANGERS, HELIUM COMPRESSORS. ACCESS CONTROL DOORS.

EQUIP. ACCESS: EXISTING 10'-0" WIDE x 10'-0" HIGH SERVICE DOORS AND 6'-0" x 9'-0" ELEVATOR WITH CURVED LABYRINTH TO TEVATRON ENCLOSURE BELOW.

DIMENSIONS: IRREGULAR SHAPE 300'-0" LONG x 50'-0" WIDE. EXISTING BUILDING 7,922 SF; 2508 SF FILLED FOR SHIELDING; 5414 SF NET. 20'-0" WIDE ADDITION TO RF GALLERY PLUS 24'-0" WIDE X 44'-0" (COL./COL.) COMPRESSOR ROOM ADDITION BOTH WITH 12'-0" CLEAR INTERIOR HEIGHT 5,425 SF. 10,840 SF. TOTAL NET.

CONSTRUCTION: NON-COMBUSTIBLE, INSULATED METAL SIDING ON STEEL FRAME, BUILT-UP ROOF, CONCRETE FLOOR.

SHIELDING: 26'-0" EARTH EQUIVALENT MAIN INJECTOR ENCLOSURE.

RF/MI-60 SERVICE BUILDING

FUNCTION: PERSONNEL/EQUIPMENT ACCESS TO MAIN INJECTOR ENCLOSURE BELOW. HIGH BAY ASSEMBLY & STAGING AREA. SPACE FOR SERVICE AND UTILITY EQUIPMENT.

CONTENTS: MAIN INJECTOR CONTROL RACKS, MI RF CAVITY AND MAGNET POWER SUPPLIES, LCW PUMPS, HEAT EXCHANGERS, DEIONIZERS. BEAM LINE MAGNET CONTROL RACKS. RIGGING AND ASSEMBLY EQUIPMENT STORAGE. ACCESS CONTROL DOORS.

EQUIP. ACCESS: 12'-0" WIDE x 13'-0" HIGH SERVICE DOOR INTO HIGH BAY. 8'-0" WIDE x 30'-0" LONG HATCH AND 8'-6" WIDE x 10'-0" DEEP ELEVATOR WITH CURVED VEHICLE LABYRINTH TO MAIN INJECTOR ENCLOSURE BELOW.

DIMENSIONS: IRREGULAR SHAPE. 100'-0" LONG x 50'-0" WIDE HIGH BAY WITH 18'-0" CLEAR INTERIOR HEIGHT AND 450'-0" LONG x 50'-0" WIDE LOW BAY WITH 12'-0" CLEAR INTERIOR HEIGHT. TOTAL 25,000 S.F.

ELEVATION: FLOOR @ ELEV. 742'-6".

CONSTRUCTION: NON-COMBUSTIBLE, INSULATED METAL SIDING ON STEEL FRAME, BUILT-UP ROOF, CONCRETE FLOOR. FIRE WALL ADJACENT TO TRANSFORMERS

BRIDGE CRANE: 25 TON CRANE WITH 18'-0" CLEAR HOOK

SHIELDING: 26'-0" EARTH EQUIVALENT MAIN INJECTOR ENCLOSURE.

MAIN INJECTOR COOLING PONDS

FUNCTION: PRIMARY HEAT REJECTION TO AIR. COLLECTION AND DETENTION OF STORM WATER RUNOFF. CHANNEL FLOODWATER AROUND MAIN INJECTOR RING.

HEAT LOAD: 18.5MW OF HEAT INTO MAIN INJECTOR PONDS, 4.9MW OF HEAT INTO ADJACENT TeV COOLING PONDS (23.4MW TOTAL). HEAT FROM MAGNETS, POWER SUPPLIES, AND OTHER EQUIPMENT VIA LCW COOLING SYSTEM THROUGH HEAT EXCHANGERS TO COOLING PONDS.

DIMENSIONS: 30'-0" TO 90'-0" WIDE, 7'-0" MAXIMUM DEPTH, 4'-6" AVERAGE DEPTH, 11,900' LONG. 17.4 ACRES.

FEATURES: TRANSVERSE CONCRETE DAMS FOR POND ELEVATION/FLOW CONTROL AND INTAKE/DISCHARGE SEPARATION. POND WATER PUMPS IN BELOW GRADE CONCRETE MANHOLES. RIP-RAP ON BANKS FOR SOIL EROSION CONTROL.

MAIN INJECTOR ROAD

FUNCTION: PROVIDE PERMANENT ROAD ACCESS FOR ALL MAIN INJECTOR SERVICE BUILDINGS, PONDS AND EQUIPMENT. PROVIDE CONSTRUCTION ACCESS DURING ALL PHASES OF CONSTRUCTION.

DIMENSIONS: 22'-0" WIDE WITH 4'-0" SHOULDER EACH SIDE. 8,500' LONG.

ELEVATIONS: VARIES 739.0' TO 747.0'

GRADE: 2% MAXIMUM ON ROADS AND SERVICE DRIVES.

CONSTRUCTION: 1'-6" GRANULAR SUB-BASE & BASE FOR CONSTRUCTION PHASE. REGRADING AND 3" BITUMINOUS CONCRETE PAVEMENT AFTER COMPLETION OF CONSTRUCTION.

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	C. FEDEROWICZ	
DRAWN	C. FEDEROWICZ	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

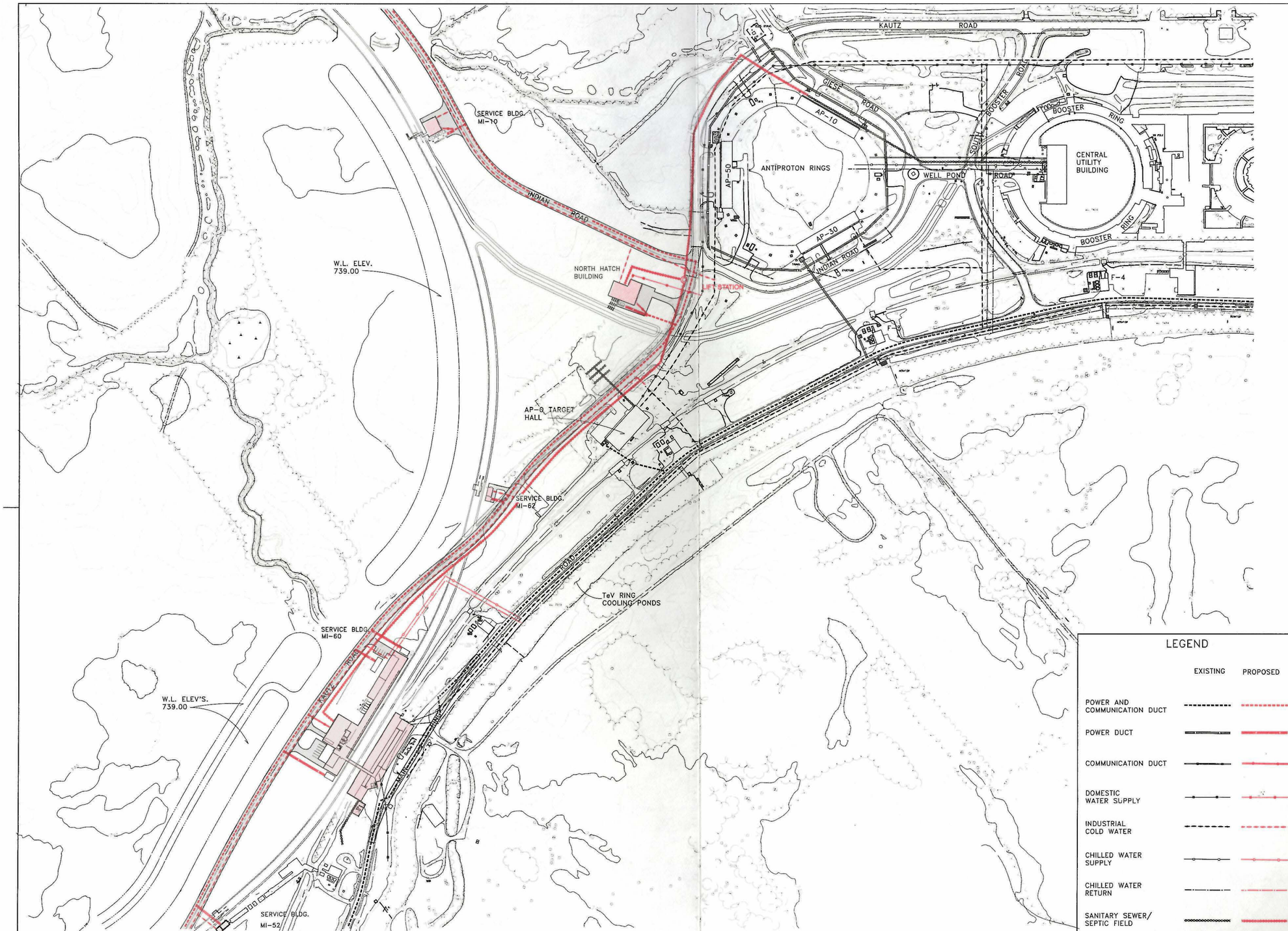
SCALE: 1" = 200'-0" (200 0 200 400 SCALE FEET)

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
SITE CRITERIA PLAN

DRAWING NO. 6-6-1 CDR-6 REV. OCT. 1991

10:17:58a.m. 24OCT91



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	C. FEDEROWICZ	
DRAWN	C. FEDEROWICZ	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 100'-0" (100 0 100 200 SCALE FEET)

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

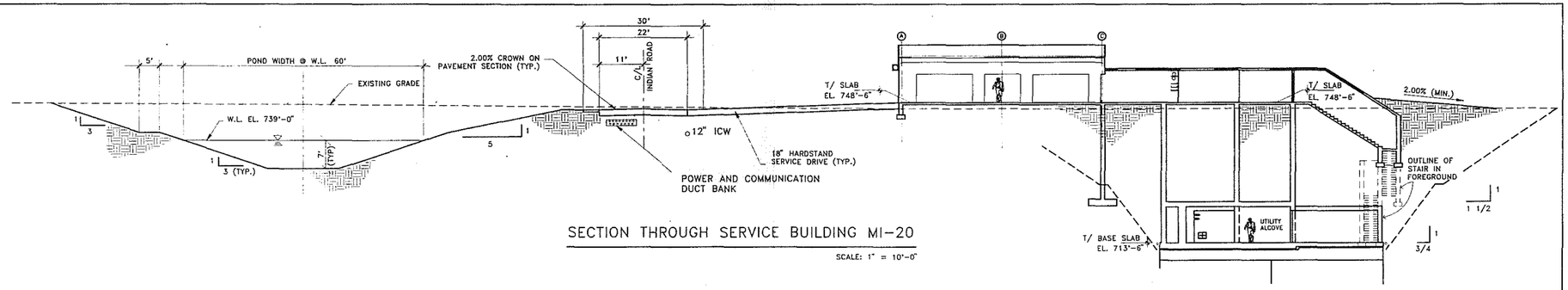
FERMILAB MAIN INJECTOR
UTILITY PLAN

DRAWING NO. 6-6-1 CDR-7 REV.

OCT. 1991

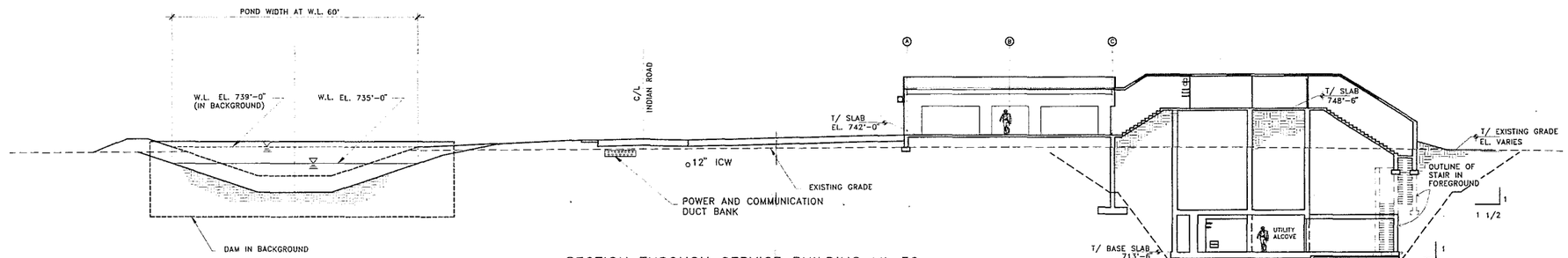
03:48:58p.m. 22OCT91

CDR-7



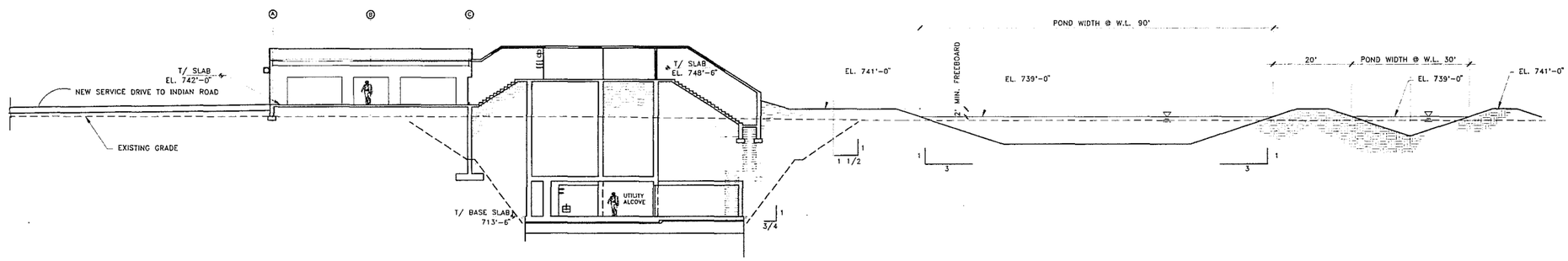
SECTION THROUGH SERVICE BUILDING MI-20

SCALE: 1" = 10'-0"



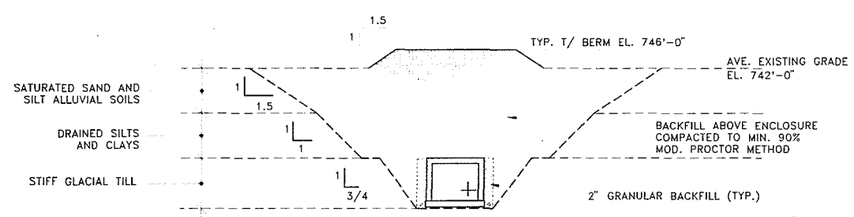
SECTION THROUGH SERVICE BUILDING MI-30

SCALE: 1" = 10'-0"



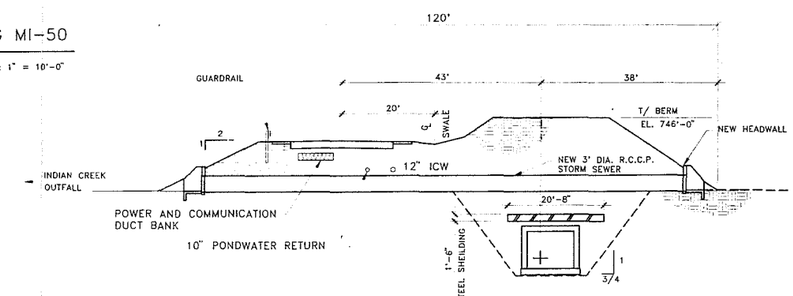
SECTION THROUGH SERVICE BUILDING MI-50

SCALE: 1" = 10'-0"



TYPICAL OPEN CUT EXCAVATION DETAIL

SCALE: 1" = 10'-0"



SECTION THROUGH INDIAN CREEK OUTFALL

SCALE: 1" = 10'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

PLOT-DATE

	NAME	DATE
DESIGNED	C. FEDEROWICZ	
DRAWN	C. FEDEROWICZ	
CHECKED		
APPROVED		
SUBMITTED		

SCALE: 1" = 10'-0" (10 0 10 20 SCALE FEET)

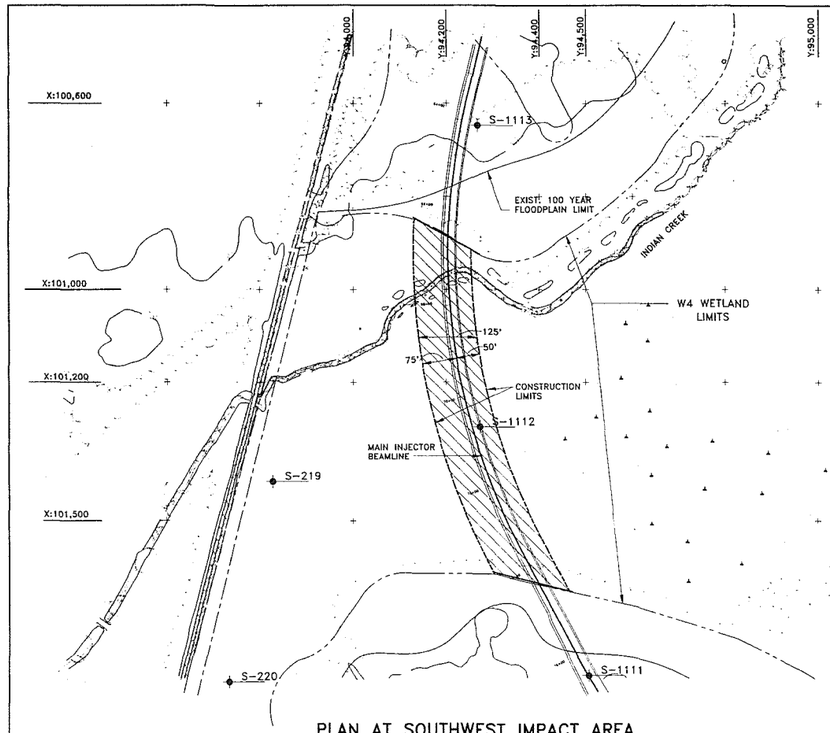
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
EXCAVATION SECTIONS

DRAWING NO. 6-6-1 CDR-8 REV.

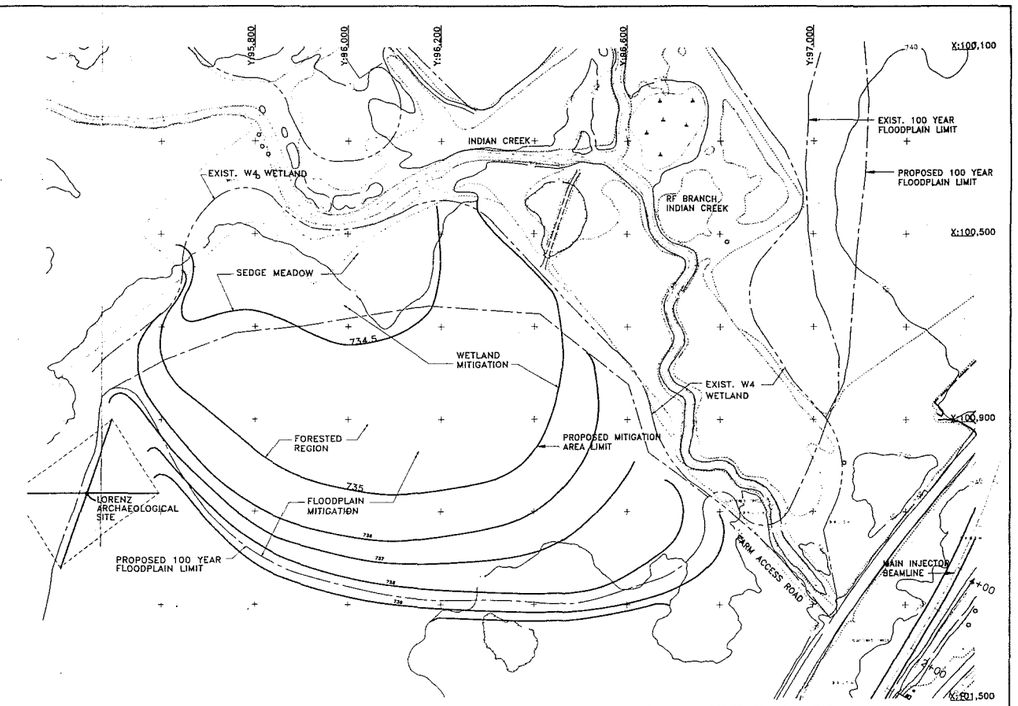
OCT. 1991

CDR-8



PLAN AT SOUTHWEST IMPACT AREA

SCALE: 1" = 100'-0"

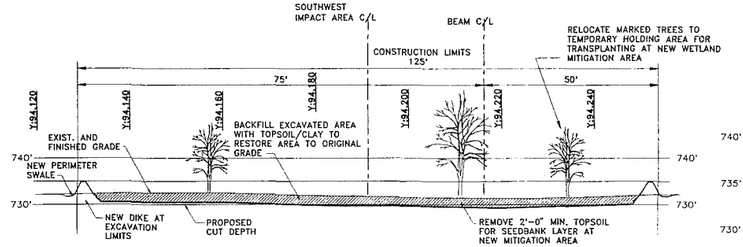


PLAN AT MITIGATION AREA

SCALE: 1" = 100'-0"

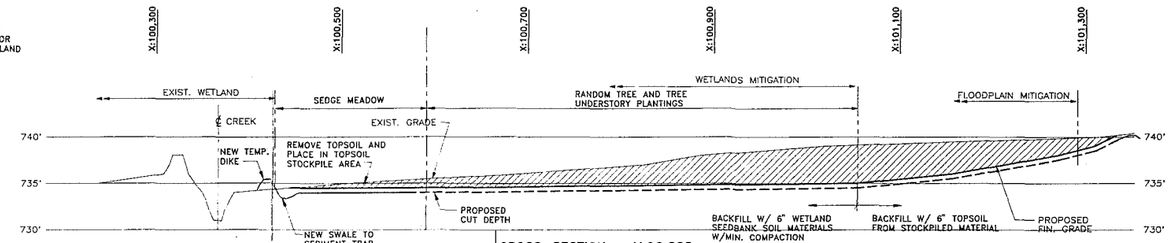
REQUIRED COMPENSATORY AREAS

8.6 ACRES COMPENSATORY WETLANDS
29 ACRE-FEET OF COMPENSATORY FLOODPLAIN STORAGE



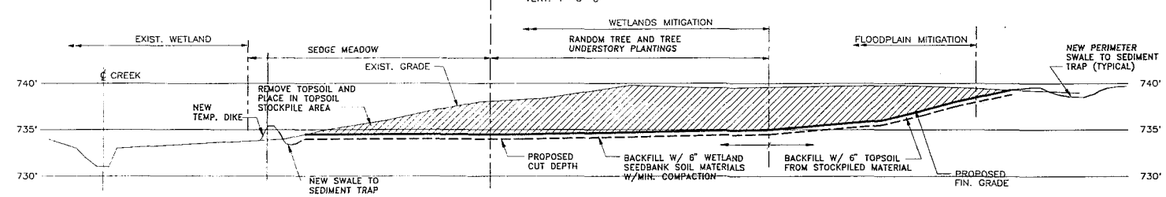
CROSS-SECTION – X:101.120

SCALE: 1" = 10'-0" (LOOKING WEST)



CROSS-SECTION – Y:96.200

SCALE: HOR. 1"=50'-0" VERT. 1"=5'-0" (LOOKING NORTH)



CROSS-SECTION – Y:95.800

SCALE: HOR. 1"=50'-0" VERT. 1"=5'-0" (LOOKING NORTH)

ENVIRONMENTAL APPROVAL ACTIONS

PERMITS

AGENCY	ACTION REQUESTED	ISSUED
DEPARTMENT OF THE ARMY CHICAGO DISTRICT, U.S. CORPS OF ENGINEERS CHICAGO, ILLINOIS	CLEAN WATER ACT SECTION 404, NATIONWIDE 26 PERMIT APPLICATION NO. 3459102	JUNE 26, 1991
DIVISION OF WATER POLLUTION CONTROL ILLINOIS ENVIRONMENTAL PROTECTION AGENCY SPRINGFIELD, ILLINOIS	CLEAN WATER ACT SECTION 401, WATER QUALITY CERTIFICATION	JUNE 4, 1991
ILLINOIS DAM SAFETY SECTION ILLINOIS DEPT. OF TRANSPORTATION DIVISION OF WATER RESOURCES SPRINGFIELD, ILLINOIS	SECTION 70 (FLOOD CONTROL) AND SECTION 70A (CONSTRUCTION OF CLASS III DAM) (RIVERS, LAKES AND STREAMS ACT)	OCT. 1, 1990
U.S. ENVIRONMENTAL PROTECTION AGENCY REGION V (5AC-26) CHICAGO, ILLINOIS	APPLICATION FOR PERMIT TO CONSTRUCT 40 CFR PART 61.07 RADIONUCLIDES NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTIONS (NESHAP) REF: 5AT-26	MAY 9, 1991
DIVISION OF AIR POLLUTION CONTROL ILLINOIS ENVIRONMENTAL PROTECTION AGENCY SPRINGFIELD, ILLINOIS	APPLICATION FOR PERMIT TO CONSTRUCT IL ADM. CODE 201.142 NESHAP ID# 043B 07AAI	APRIL 1, 1991
U.S. DEPT. OF AGRICULTURE SOIL CONSERVATION SERVICE CHAMPAIGN, ILLINOIS	FARMLAND CONVERSION IMPACT RATING	SEPT. 18, 1991

CONSULTATIONS

AGENCY	CONSULTATION REQUESTED	
U.S. FISH & WILDLIFE SERVICE ROCK ISLAND, ILLINOIS	CONSULTATION IN ACCORDANCE WITH FISH & WILDLIFE COORDINATION ACT 48 STAT. 401 16 U.S.C. 661 ENDANGERED SPECIES ACT	APRIL 30, 1991
ILLINOIS DEPT. OF CONSERVATION SPRINGFIELD, ILLINOIS	CONSULTATION IN ACCORDANCE WITH FISH AND WILDLIFE COORDINATION ACT	JUNE 20, 1991
STATE HISTORICAL PRESERVATION OFFICER ILLINOIS HISTORIC PRESERVATION AGENCY SPRINGFIELD, ILLINOIS	106 DETERMINATION OF NO EFFECT 36 CFR 800	JULY 22, 1991

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	FLUOR DANIEL, L. EVEN	
DRAWN	FLUOR DANIEL, L. EVEN	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
PLAN 1" = 100'-0"
HORIZONTAL 1" = 50'-0"
VERTICAL 1" = 5'-0"
1" = 10'-0"

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
MITIGATION AREA PLANS AND PROFILES

DRAWING NO. 6-6-1 CDR-9 REV.

OCT. 1991

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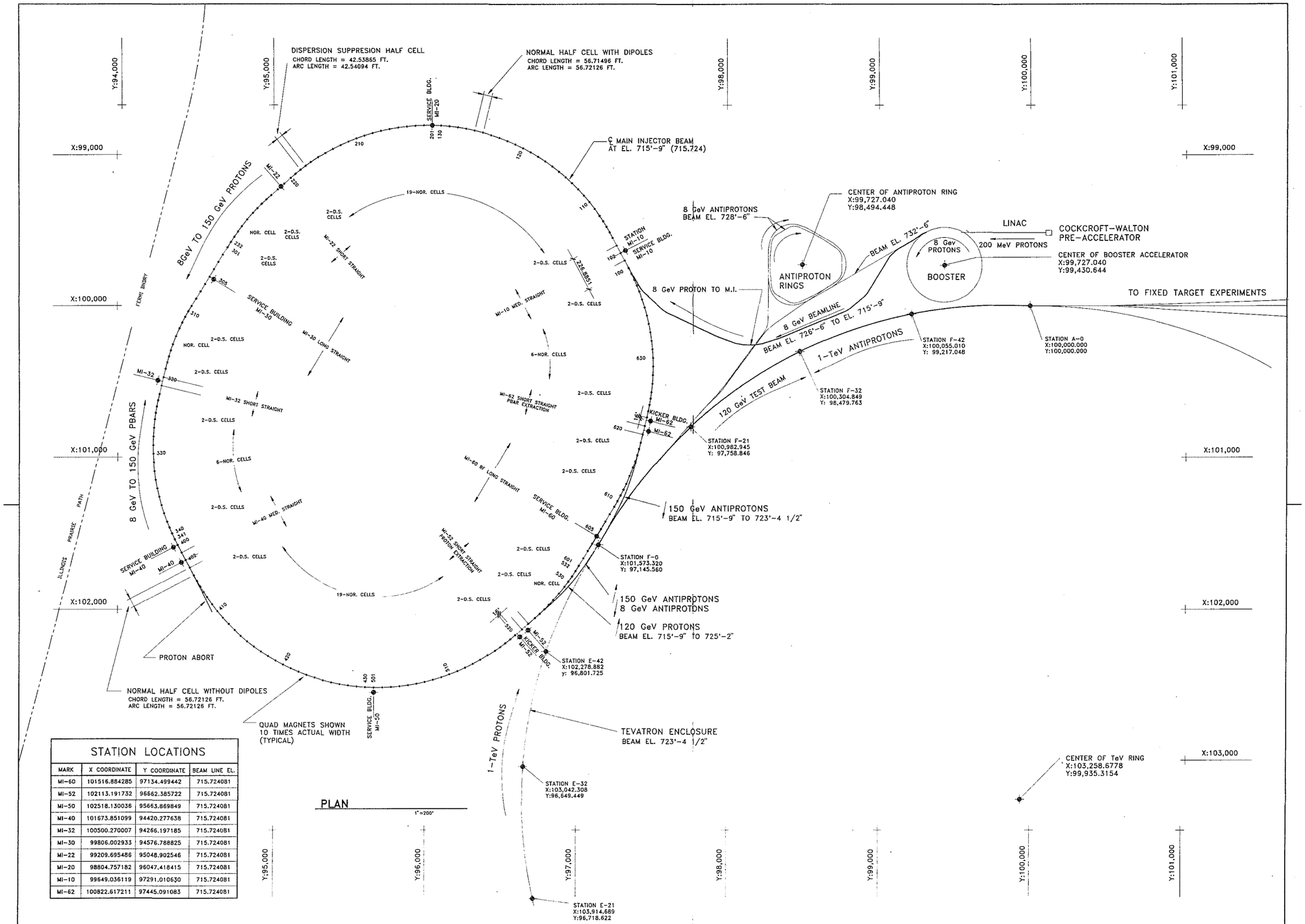

STATION LOCATIONS

MARK	X COORDINATE	Y COORDINATE	BEAM LINE EL.
MI-60	101516.884285	97134.499442	715.724081
MI-52	102113.191732	96662.385722	715.724081
MI-50	102518.130036	95663.869849	715.724081
MI-40	101673.851099	94420.277638	715.724081
MI-32	100500.270007	94266.197185	715.724081
MI-30	99806.002933	94576.788825	715.724081
MI-22	99209.695486	95048.902546	715.724081
MI-20	98804.757182	96047.418415	715.724081
MI-10	99649.036119	97291.010630	715.724081
MI-62	100822.617211	97445.091083	715.724081

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	TOMSKI	
DRAWN	TOMSKI	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 200'-0" (200 0 200 400 SCALE FEET)

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
BEAMLINE GEOMETRICS

DRAWING NO. 6-6-1 CDR-10 REV.

OCT. 1991

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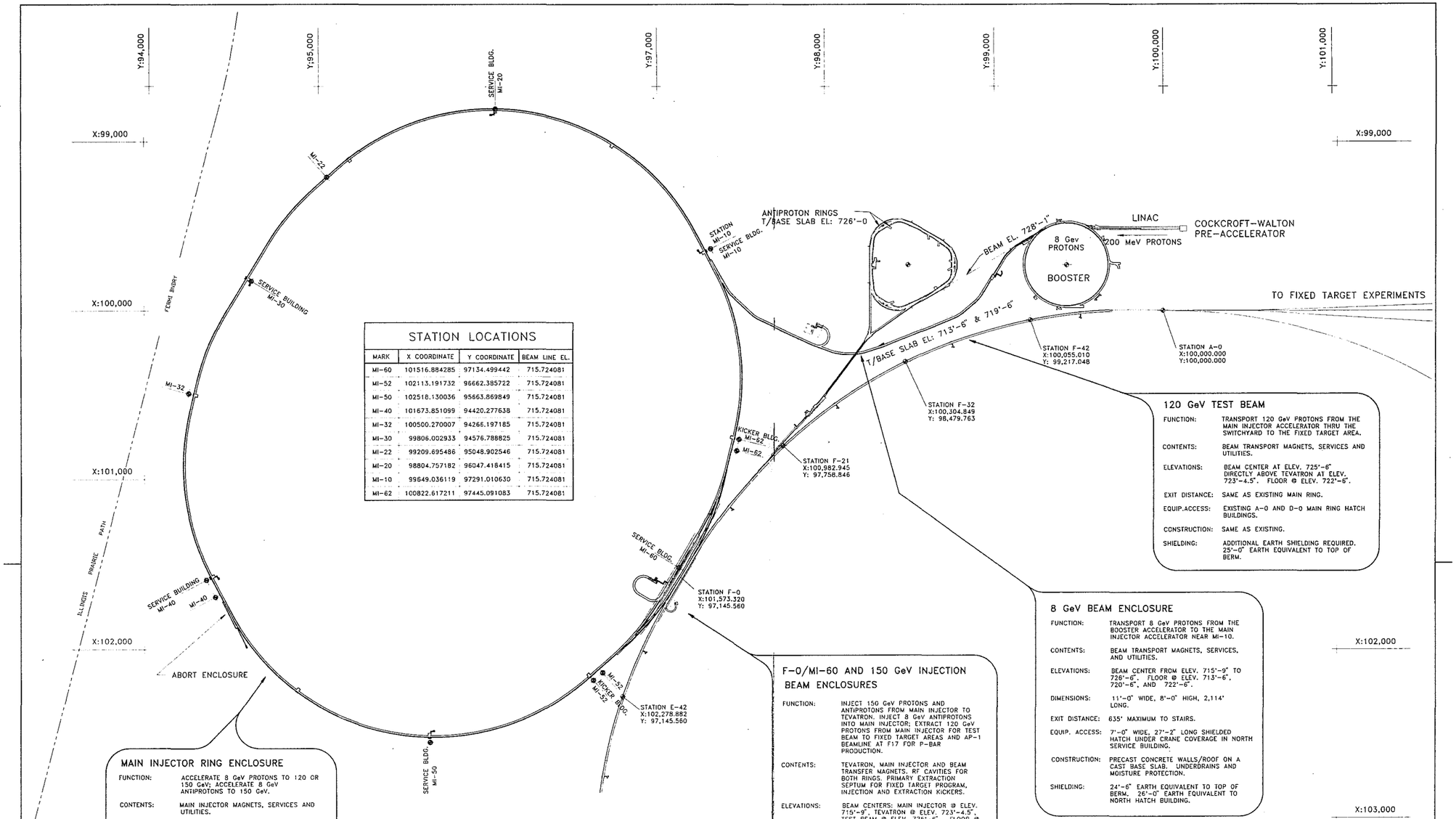
CDR-10



STATION LOCATIONS

MARK	X COORDINATE	Y COORDINATE	BEAM LINE EL.
MI-60	101516.884285	97134.499442	715.724081
MI-52	102113.191732	96662.385722	715.724081
MI-50	102518.130036	95663.869849	715.724081
MI-40	101673.851099	94420.277638	715.724081
MI-32	100500.270007	94266.197185	715.724081
MI-30	99806.002933	94576.788825	715.724081
MI-22	99209.695486	95048.902546	715.724081
MI-20	98804.757182	96047.418415	715.724081
MI-10	99649.036119	97291.010630	715.724081
MI-62	100822.617211	97445.091083	715.724081

120 GeV TEST BEAM

FUNCTION: TRANSPORT 120 GeV PROTONS FROM THE MAIN INJECTOR ACCELERATOR THRU THE SWITCHYARD TO THE FIXED TARGET AREA.

CONTENTS: BEAM TRANSPORT MAGNETS, SERVICES AND UTILITIES.

ELEVATIONS: BEAM CENTER AT ELEV. 725'-6" DIRECTLY ABOVE TEVATRON AT ELEV. 723'-4.5". FLOOR @ ELEV. 722'-6".

EXIT DISTANCE: SAME AS EXISTING MAIN RING.

EQUIP.ACCESS: EXISTING A-0 AND D-0 MAIN RING HATCH BUILDINGS.

CONSTRUCTION: SAME AS EXISTING.

SHIELDING: ADDITIONAL EARTH SHIELDING REQUIRED. 25'-0" EARTH EQUIVALENT TO TOP OF BERM.

8 GeV BEAM ENCLOSURE

FUNCTION: TRANSPORT 8 GeV PROTONS FROM THE BOOSTER ACCELERATOR TO THE MAIN INJECTOR ACCELERATOR NEAR MI-10.

CONTENTS: BEAM TRANSPORT MAGNETS, SERVICES, AND UTILITIES.

ELEVATIONS: BEAM CENTER FROM ELEV. 715'-9" TO 726'-6". FLOOR @ ELEV. 713'-6", 720'-6", AND 722'-6".

DIMENSIONS: 11'-0" WIDE, 8'-0" HIGH, 2,114' LONG.

EXIT DISTANCE: 635' MAXIMUM TO STAIRS.

EQUIP. ACCESS: 7'-0" WIDE, 27'-2" LONG SHIELDED HATCH UNDER CRANE COVERAGE IN NORTH SERVICE BUILDING.

CONSTRUCTION: PRECAST CONCRETE WALLS/ROOF ON A CAST BASE SLAB. UNDERDRAINS AND MOISTURE PROTECTION.

SHIELDING: 24'-6" EARTH EQUIVALENT TO TOP OF BERM. 26'-0" EARTH EQUIVALENT TO NORTH HATCH BUILDING.

F-0/MI-60 AND 150 GeV INJECTION BEAM ENCLOSURES

FUNCTION: INJECT 150 GeV PROTONS AND ANTIPROTONS FROM MAIN INJECTOR TO TEVATRON. INJECT 8 GeV ANTIPROTONS INTO MAIN INJECTOR; EXTRACT 120 GeV PROTONS FROM MAIN INJECTOR FOR TEST BEAM TO FIXED TARGET AREAS AND AP-1 BEAMLINE AT F17 FOR P-BAR PRODUCTION.

CONTENTS: TEVATRON, MAIN INJECTOR AND BEAM TRANSFER MAGNETS. RF CAVITIES FOR BOTH RINGS. PRIMARY EXTRACTION SEPTUM FOR FIXED TARGET PROGRAM, INJECTION AND EXTRACTION KICKERS.

ELEVATIONS: BEAM CENTERS: MAIN INJECTOR @ ELEV. 715'-9". TEVATRON @ ELEV. 723'-4.5", TEST BEAM @ ELEV. 725'-6". FLOOR @ ELEV. 713'-6", 719'-6" AND 722'-6".

DIMENSIONS: WIDTH VARIES, 9'-0" HIGH AT M.I. RF, 8'-0" TO 14'-0" HIGH AT TANGENTS TO TEVATRON.

EXIT DISTANCE: 570' MAXIMUM TO STAIRS.

EQUIP. ACCESS: EXISTING LABYRINTH 6'-0" WIDE, 7'-0" HIGH. EXISTING ELEVATOR 6' WIDE, 9' DEEP IN RF/F-0 SERVICE BUILDING. NEW 8'-0" WIDE, 30'-0" LONG HATCH UNDER CRANE COVERAGE AND 8'-6" WIDE, 10'-0" DEEP ELEVATOR WITH CURVED VEHICLE LABYRINTH IN RF/MI-60 SERV. BLDG. 2-15 TON MONORAIL HOISTS AT A-15 TRANSITION TO MAIN INJECTOR.

CONSTRUCTION: CAST-IN-PLACE CONCRETE. UNDERDRAINS AND MOISTURE PROTECTION. PENETRATIONS TO F-0/MI-60 SERVICE BUILDING ABOVE.

SHIELDING: 26'-0" EARTH EQUIVALENT TO F-0/MI-60 SERVICE BUILDINGS ABOVE. 26'-0" EARTH EQUIVALENT TO TOP OF BERM.

MAIN INJECTOR RING ENCLOSURE

FUNCTION: ACCELERATE 8 GeV PROTONS TO 120 OR 150 GeV; ACCELERATE 8 GeV ANTIPROTONS TO 150 GeV.

CONTENTS: MAIN INJECTOR MAGNETS, SERVICES AND UTILITIES.

ELEVATIONS: BEAM CENTER @ ELEV. 715'-9". FLOOR SLAB AT ELEV. 713'-6".

DIMENSIONS: 10'-0" WIDE, 8'-0" HIGH, 10,900 FEET LONG. 109,000 S.F. 9'-0" HIGH AT UTILITY ALCOVES.

EXIT DISTANCE: 1,050' MAXIMUM TO STAIRS.

EQUIP. ACCESS: 10'-0" WIDE, 30'-0" LONG HATCH AND CURVED VEHICLE ACCESS LABYRINTH UNDER CRANE COVERAGE IN MI-60 BEAM ENCLOSURE. UTILITY ALCOVES AT AND MIDWAY BETWEEN SERVICE BUILDINGS. STAIRS AT ALL SERVICE BUILDINGS.

CONSTRUCTION: PRECAST CONCRETE WALLS/ROOF ON CAST BASE SLAB. CAST-IN-PLACE CONCRETE UNDER SERVICE BUILDINGS AND AT ENCLOSURE BRANCHES AND HATCHES. UNDERDRAINS AND MOISTURE PROTECTION.

SHIELDING: 24'-6" EARTH EQUIVALENT TO TOP OF BERM SURFACE ABOVE. 26'-0" EARTH EQUIVALENT TO BUILDINGS.

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 200'-0" 200 0 200 400 SCALE FEET

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

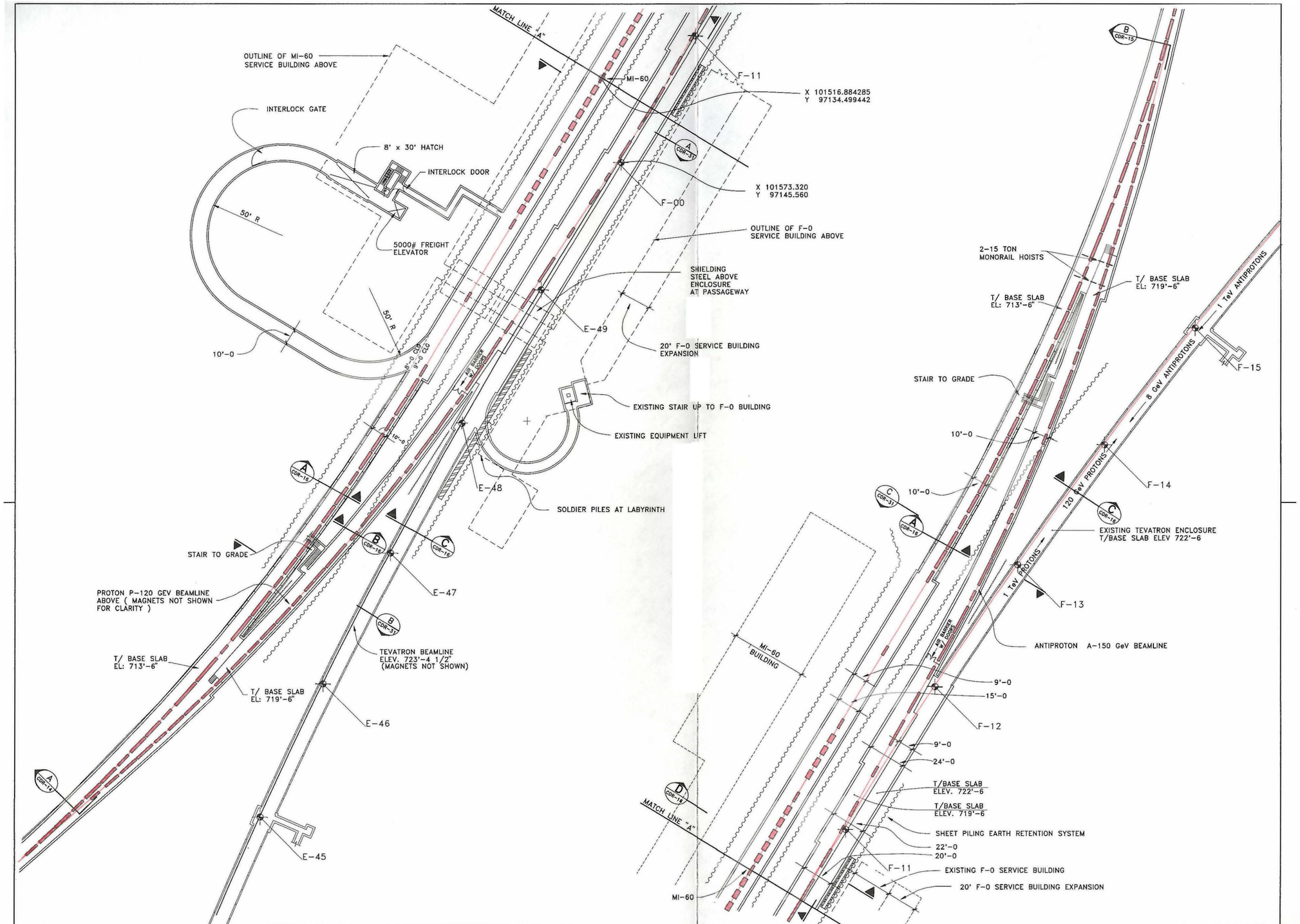
FERMILAB MAIN INJECTOR
ENCLOSURE CRITERIA PLAN

DRAWING NO 6-6-1 CDR-11 REV.

OCT. 1991

12:22:26a.m. 28OC191

CDR-11



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI / T. BURKE	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 20'-0" (20 0 20 40 SCALE FEET)

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

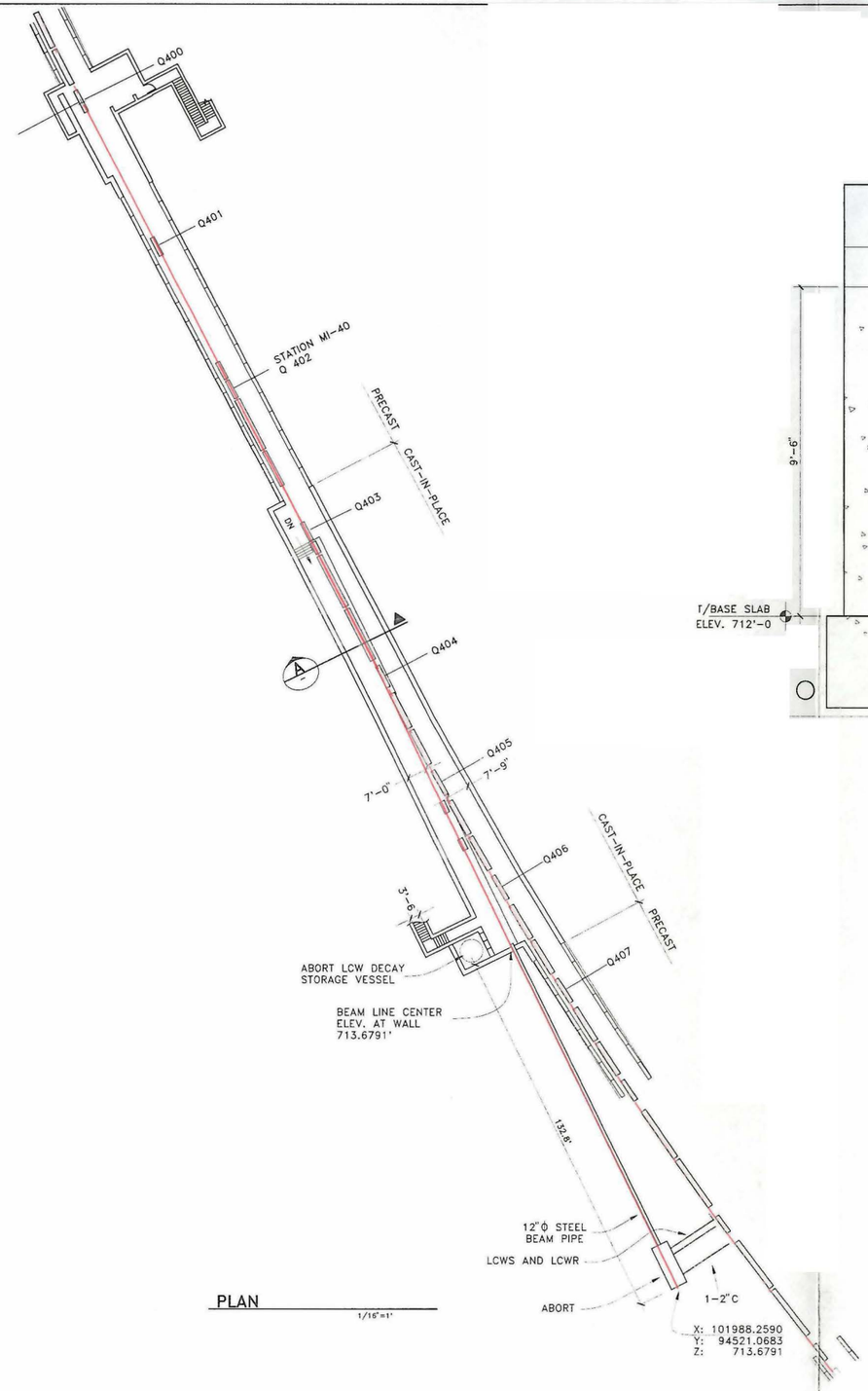
FERMILAB MAIN INJECTOR
F-0 / MI-60 ENCLOSURE PLAN

DRAWING NO. 6-6-1 CDR-12 REV.

OCT. 1991

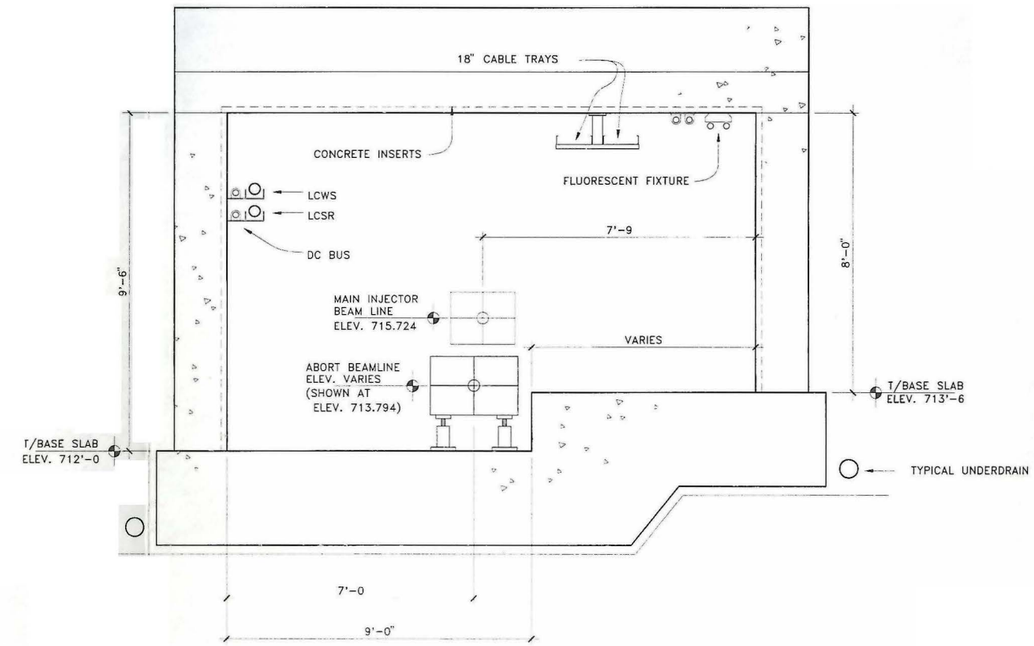
09:17:03a.m. 24OCT91

CDR-12



PLAN

1/16"=1'



SECTION A

3/4" = 1'

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T.LACKOWSKI	
DRAWN	T.LACKOWSKI / T.BURKE	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:

1/16"=1'-0" SCALE 8 0 8 16 24 32 40 FEET

3/4"=1'-0" SCALE 1 0 1 2 3 FEET

FERMI NATIONAL ACCELERATOR LABORATORY

UNITED STATES DEPARTMENT OF ENERGY

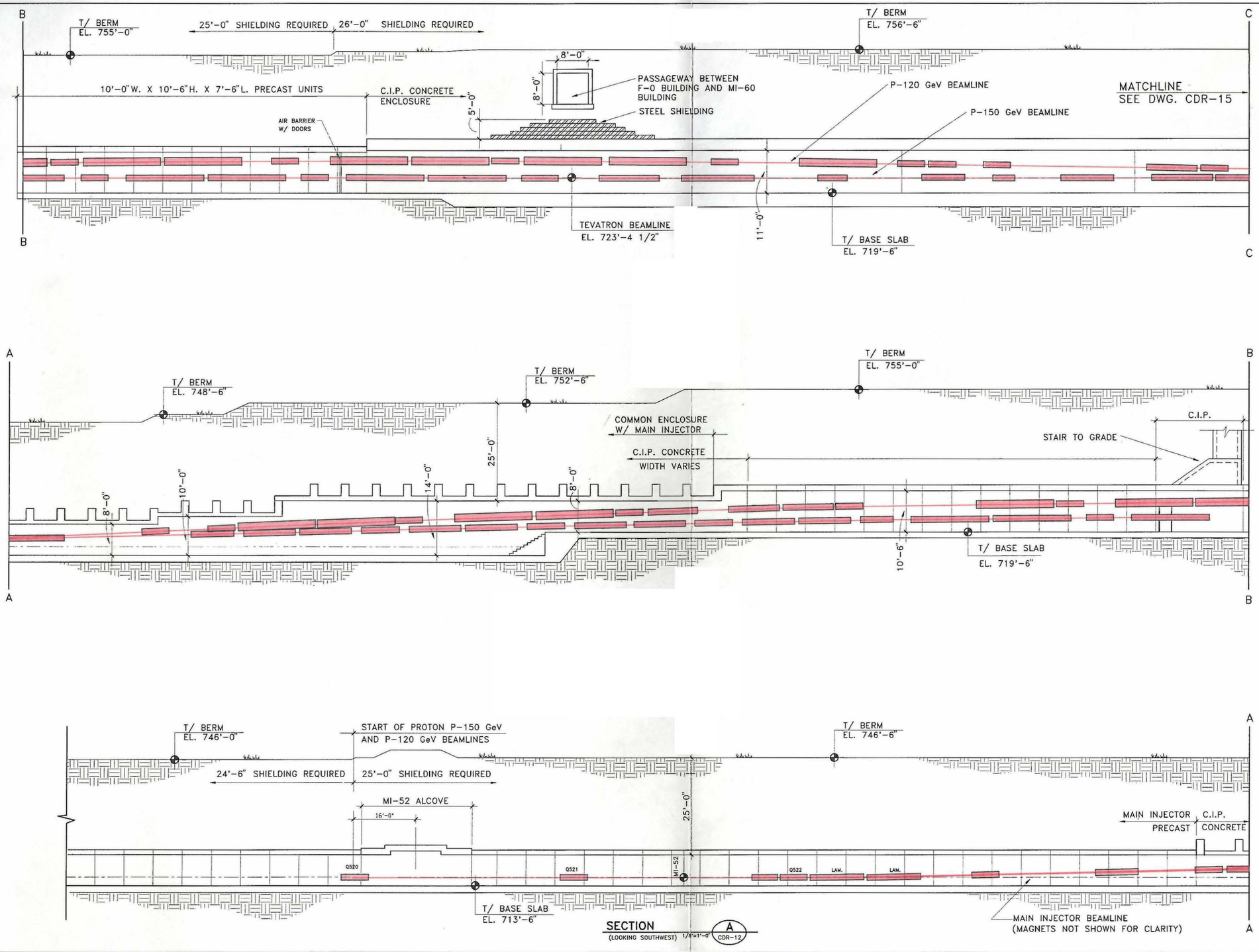
FERMILAB MAIN INJECTOR

ABORT PLAN AND SECTION

DRAWING NO. 6-6-1 CDR-13 REV.

OCT. 1991

11:21:44a.m. 24OCT91



SECTION A CDR-12
(LOOKING SOUTHWEST) 1/8"=1'-0"

REV.	DATE	DESCRIPTIONS REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI/L. JENKINS	
CHECKED		
APPROVED		
SUBMITTED		

SCALE: 1/8"=1'-0" (8 0 8 16 SCALE FEET)

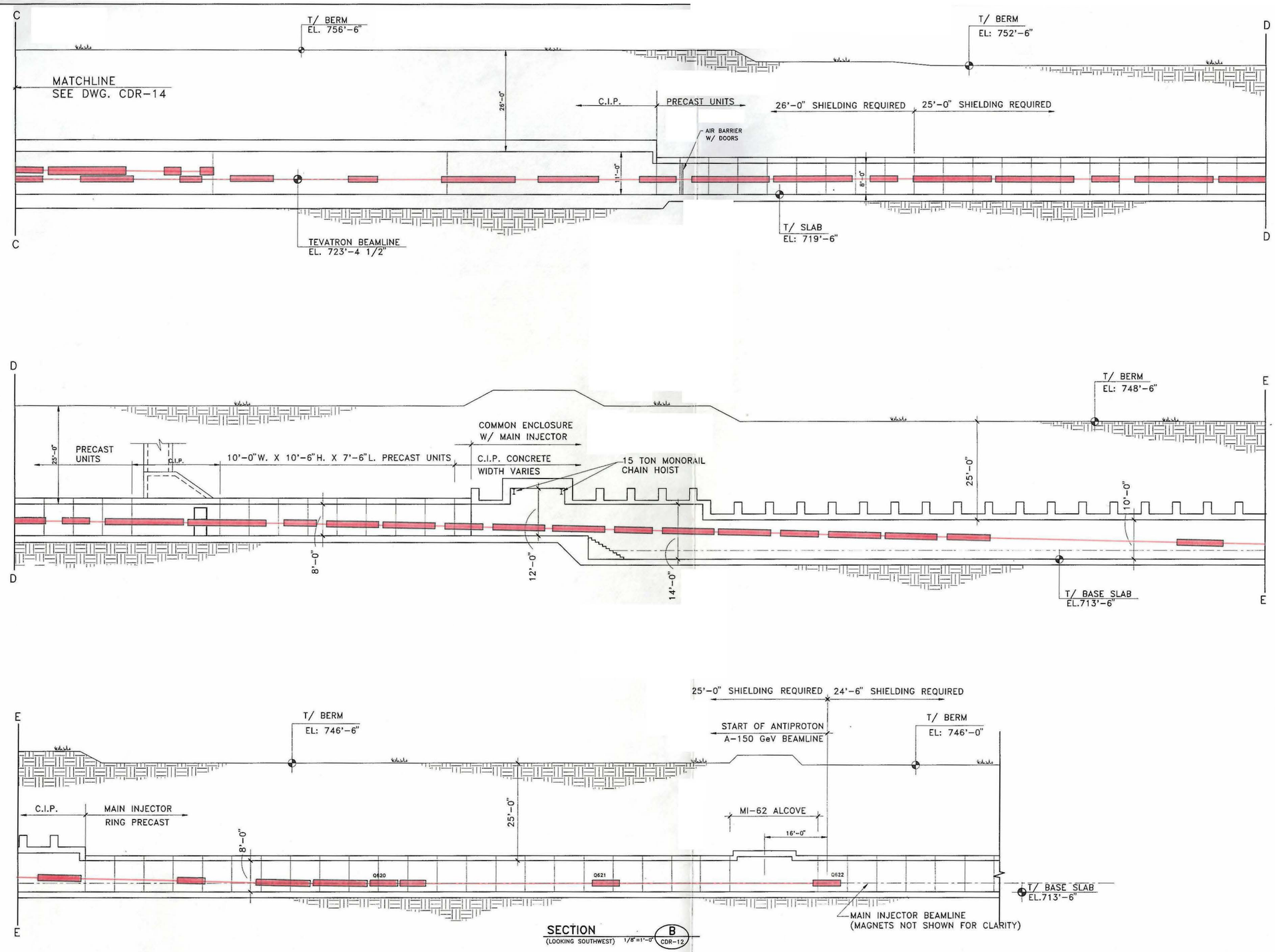
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
P-150 GeV ENCLOSURE LONG. SECTION

DRAWING NO. 6-6-1 CDR-14 REV.

OCT. 1991

03:50:56p.m. 23OCT91



SECTION B CDR-12
(LOOKING SOUTHWEST) 1/8"=1'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI/L.JENKINS	
CHECKED		
APPROVED		
SUBMITTED		

SCALE: 1/8"=1'-0" 8 0 8 16 SCALE FEET

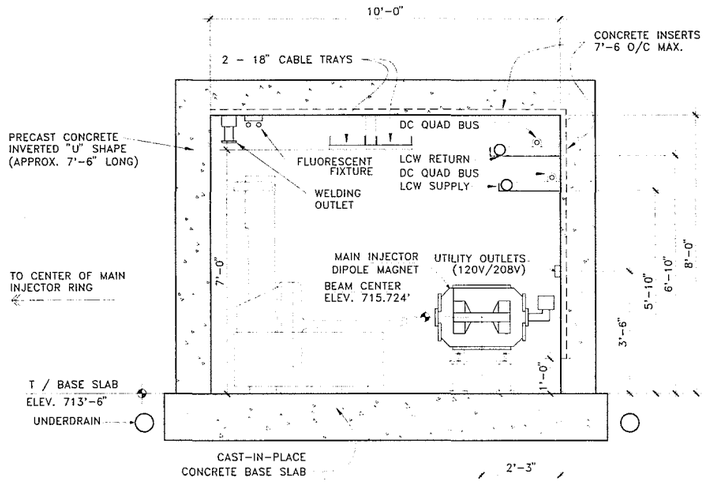
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
A-150 GeV ENCLOSURE LONG. SECTION

DRAWING NO. 6-6-1 CDR-15 REV.

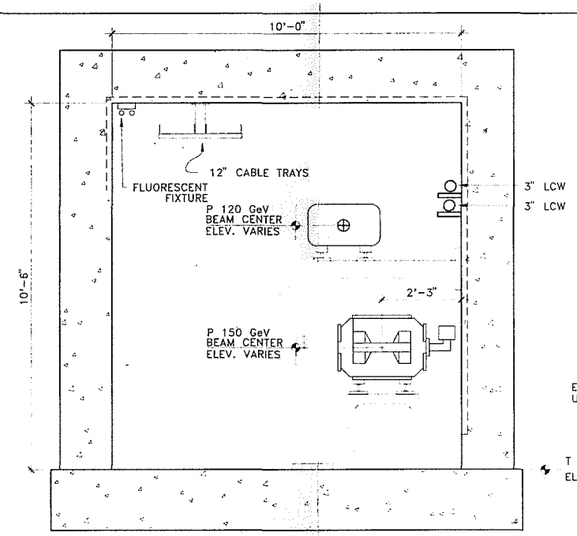
OCT. 1991

11:37:35a.m. 24OCT91



TYPICAL SECTION THROUGH MAIN INJECTOR ENCLOSURE

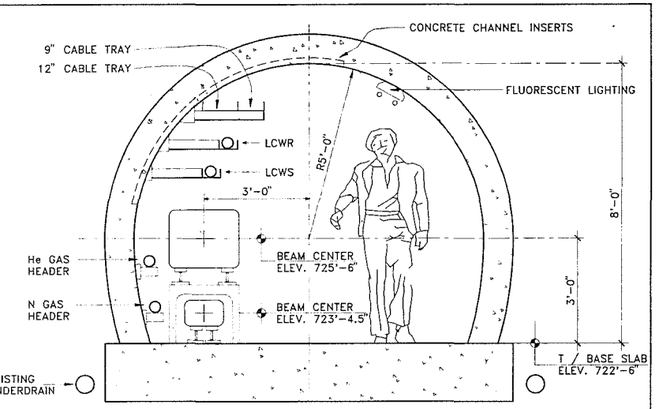
SECTION A CDR-12
3/4" = 1'-0"



P 150 ENCLOSURE SECTION

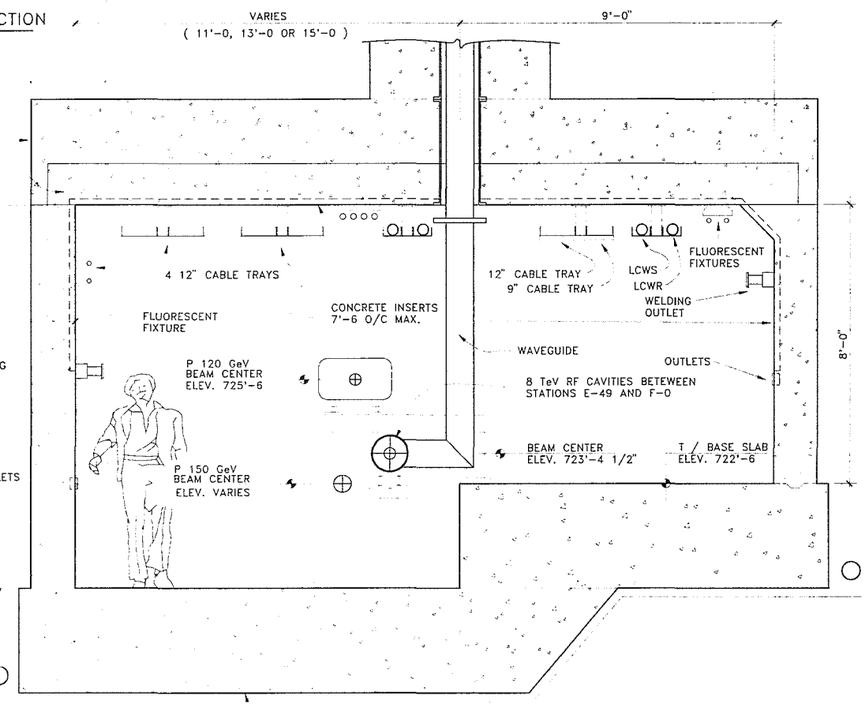
SECTION B CDR-12
3/4" = 1'-0"

CAST-IN-PLACE CONCRETE
ON PRECAST BEAMS-
COMPOSITE CONSTRUCTION



EXISTING TEVATRON RING ENCLOSURE
BETWEEN F-0 AND A-0

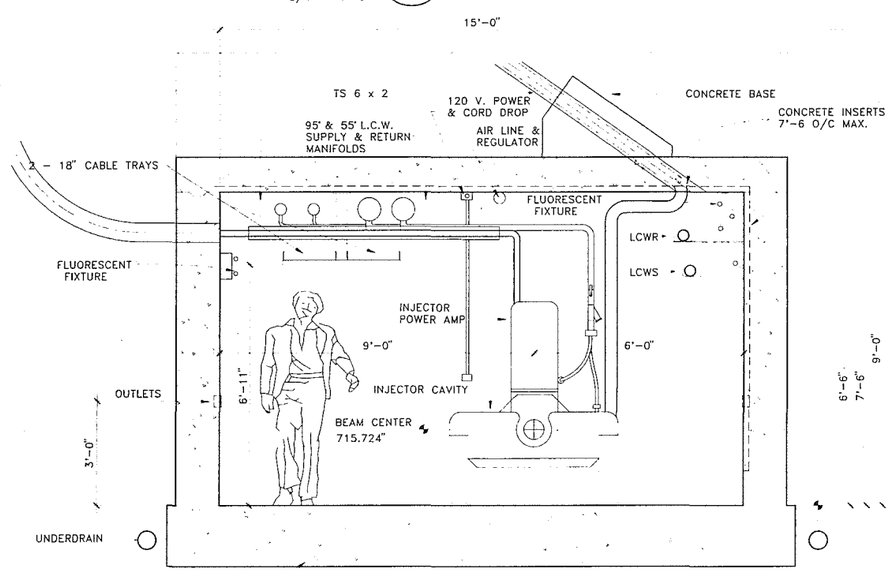
SECTION C CDR-12
3/4" = 1'-0"



F-0 ENCLOSURE

CAST-IN-PLACE CONCRETE

SECTION D CDR-12
3/4" = 1'-0"



MI-60 ENCLOSURE

CAST-IN-PLACE CONCRETE

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI / T. BURKE	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:
3/4"=1'-0" 1 0 1 2 3 SCALE FEET

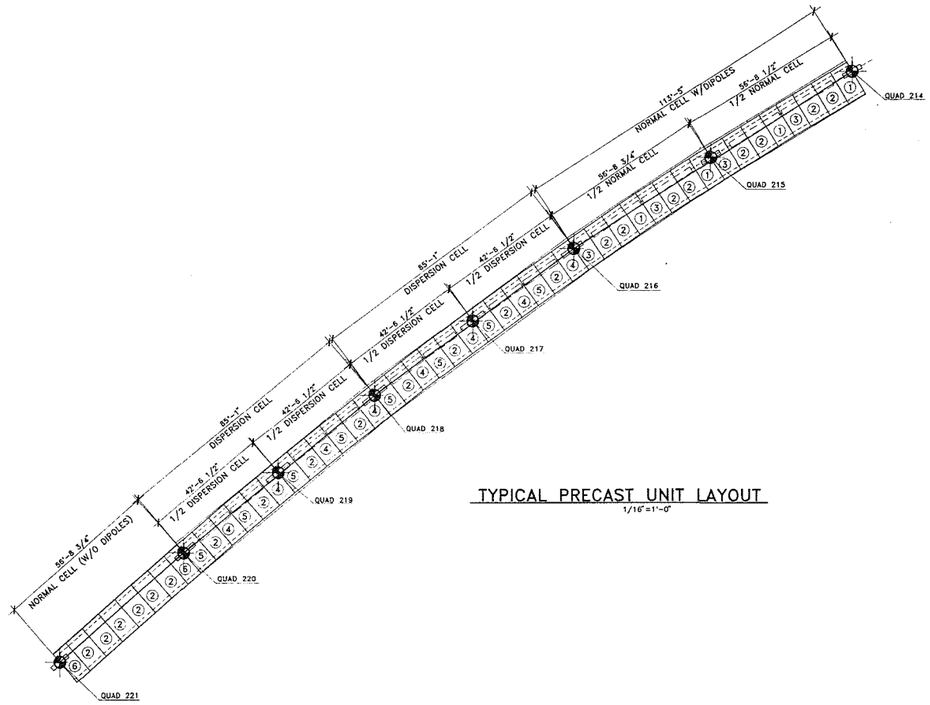
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
INJECTOR ENCLOSURE SECTIONS

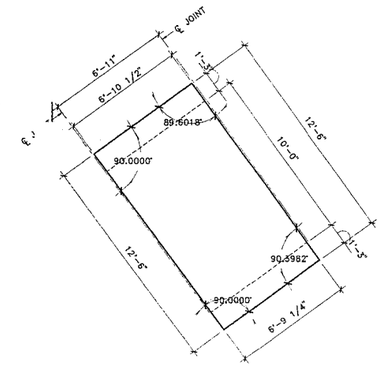
DRAWING NO. 6-6-1 CDR-16 REV.

OCT. 1991

01:05:32a.m. 24OCT91

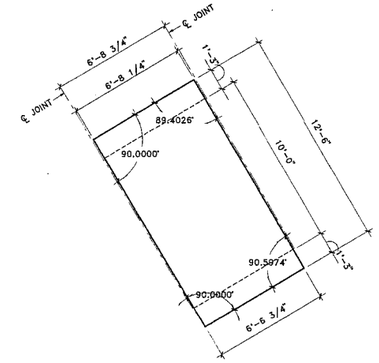


TYPICAL PRECAST UNIT LAYOUT
1/16"=1'-0"



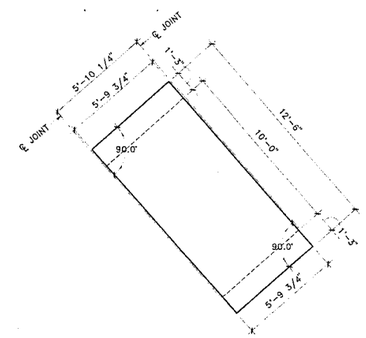
PRECAST UNIT TYPE "4"
3/8"=1'-0"

PRECAST UNIT TYPE "5" (OPPOSITE HAND)
3/8"=1'-0"

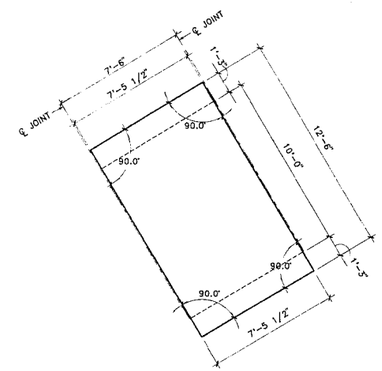


PRECAST UNIT TYPE "1"
3/8"=1'-0"

PRECAST UNIT TYPE "3" (OPPOSITE HAND)
3/8"=1'-0"



PRECAST UNIT TYPE "6"
3/8"=1'-0"

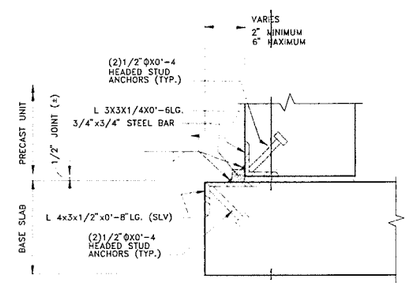


PRECAST UNIT TYPE "2"
3/8"=1'-0"

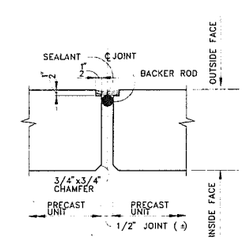
TYP. NORMAL CELL (W/O DIPOLES) PRECAST PLACING SCHED.			
ENCLOSURE SEGMENT	WORK POINT #	DISTANCE FROM STATION POINT TO WORK POINT ON REFERENCE LINE	PERPENDICULAR OFFSET FROM REFERENCE LINE TO WORK POINT
QUAD 220 THROUGH 221	220 + 0	0'-0"	2'-3"
	220 + 1	5'-10 1/4"	2'-3"
	220 + 2	13'-4 1/4"	2'-3"
	220 + 3	20'-10 1/4"	2'-3"
	220 + 4	28'-4 1/4"	2'-3"
	220 + 5	35'-10 1/4"	2'-3"
	220 + 6	43'-4 1/4"	2'-3"
	220 + 7	50'-10 1/4"	2'-3"
	221 + 0	56'-8 3/4"	2'-3"

TYP. DISPERSION CELL PRECAST PLACING SCHED.			
ENCLOSURE SEGMENT	WORK POINT #	DISTANCE FROM STATION POINT TO WORK POINT ON REFERENCE LINE	PERPENDICULAR OFFSET FROM REFERENCE LINE TO WORK POINT
QUAD 218 THROUGH 220	218 + 0	0'-0"	2'-3"
	218 + 1	6'-1 3/4"	2'-5"
	218 + 2	14'-4 3/4"	2'-7"
	218 + 3	21'-3 1/2"	2'-8 3/4"
	218 + 4	28'-2"	2'-9 1/2"
	218 + 5	35'-8"	2'-10 1/4"
	219 + 0	42'-6 1/2"	2'-10 3/4"
	219 + 1	49'-5"	2'-10 1/4"
	219 + 2	55'-11"	2'-9 1/2"
	219 + 3	63'-9 3/4"	2'-8 3/4"
	219 + 4	70'-8 1/4"	2'-7"
	219 + 5	78'-2 1/4"	2'-5"
	220 + 0	85'-1"	2'-3"

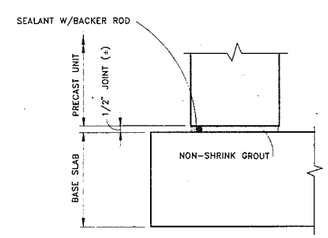
TYP. NORMAL CELL (W/DIPOLES) PRECAST PLACING SCHED.			
ENCLOSURE SEGMENT	WORK POINT #	DISTANCE FROM STATION POINT TO WORK POINT ON REFERENCE LINE	PERPENDICULAR OFFSET FROM REFERENCE LINE TO WORK POINT
QUAD 214 THROUGH QUAD 216	214 + 0	0'-0"	2'-3"
	214 + 1	6'-7 1/2"	2'-5 3/4"
	214 + 2	14'-2 1/4"	2'-8 3/4"
	214 + 3	21'-8 1/4"	2'-11 3/4"
	214 + 4	28'-4 1/4"	3'-2 1/2"
	214 + 5	35'-0 1/2"	3'-3 1/2"
	214 + 6	42'-6 1/2"	3'-4 1/2"
	214 + 7	50'-0 1/2"	3'-5 1/4"
	215 + 0	56'-8 1/2"	3'-6 1/4"
	215 + 1	63'-4 1/2"	3'-5 1/4"
	215 + 2	70'-10 1/2"	3'-4 1/2"
	215 + 3	78'-4 1/2"	3'-3 1/2"
	215 + 4	85'-0 1/2"	3'-2 1/2"
	215 + 5	91'-8 1/2"	2'-11 3/4"
	215 + 6	99'-2 3/4"	2'-8 3/4"
	215 + 7	105'-8 3/4"	2'-5 3/4"
	216 + 0	113'-5"	2'-5"



TYPICAL PRECAST ANCHOR DETAIL



TYPICAL PRECAST JOINT DETAIL
NO SCALE



TYPICAL PRECAST BASE DETAIL
NO SCALE

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	TOMSKI, MIKE GRIMSON	
DRAWN	MIKE GRIMSON	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1/16"=1'-0" SCALE 8 0 8 16 24 32 40 FEET
3/8"=1'-0" SCALE 1 0 1 2 3 4 5 6 7 FEET

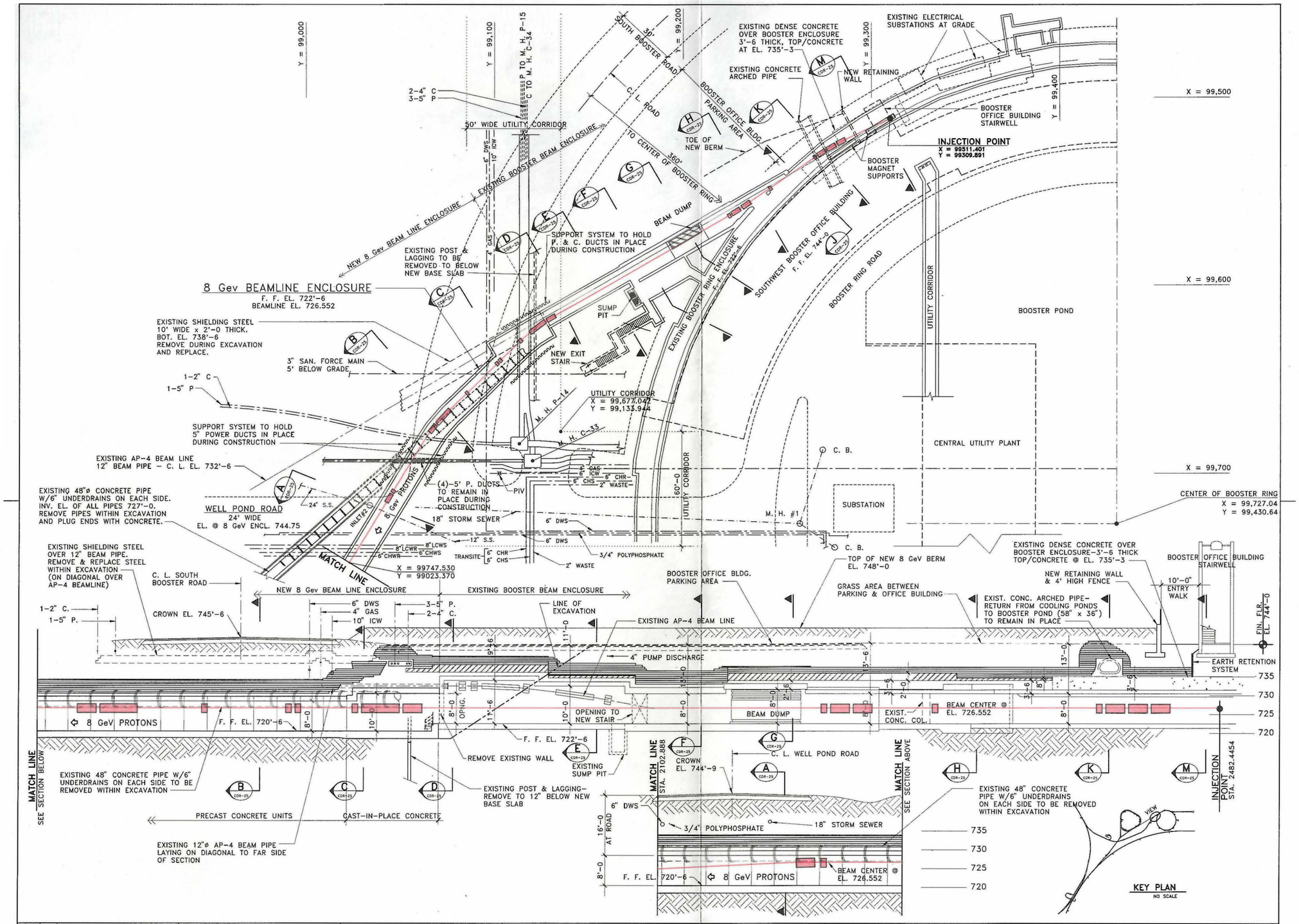
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
PRECAST ENCLOSURE DETAILS

DRAWING NO. 6-6-1 CDR-17 REV.

OCT. 1991

02/09/01a.m. 240C191



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	J. HACKEMER, LACKOWSKI	
DRAWN	J. HACKEMER	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1/16"=1'-0" PLAN SCALE
1/8"=1'-0" SECTION SCALE

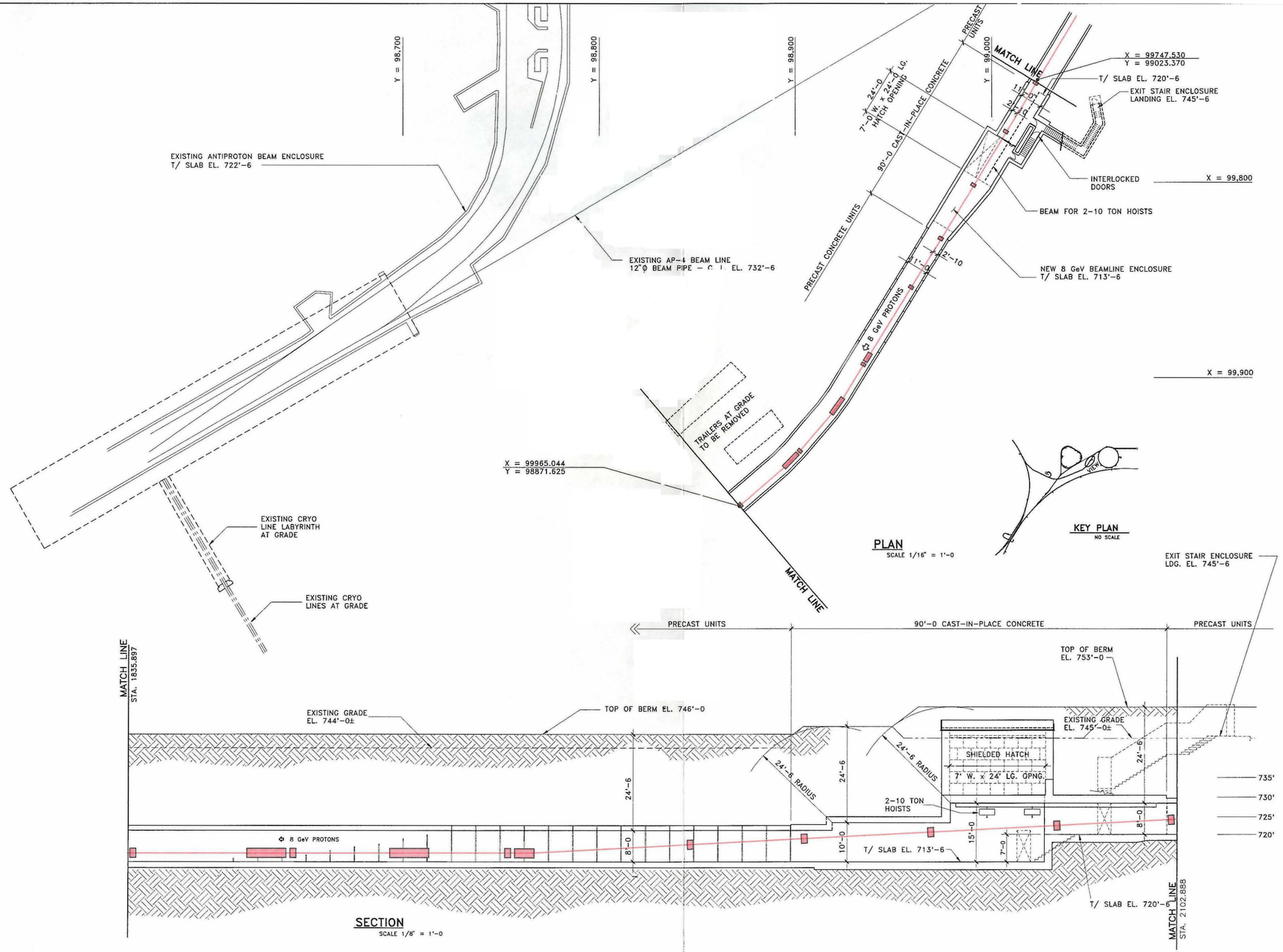
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
8 GeV BEAMLINE SHT. 1

DRAWING NO. 6-6-1 CDR-18 REV.

OCT. 1991

03:46:54p.m. 28OCT91



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	J. HACKEMER	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1/16"=1'-0" SCALE 8 0 8 16 24 32 40 FEET
PLAN SCALE
1/8"=1'-0" SCALE 8 0 8 16 FEET
SECTION SCALE

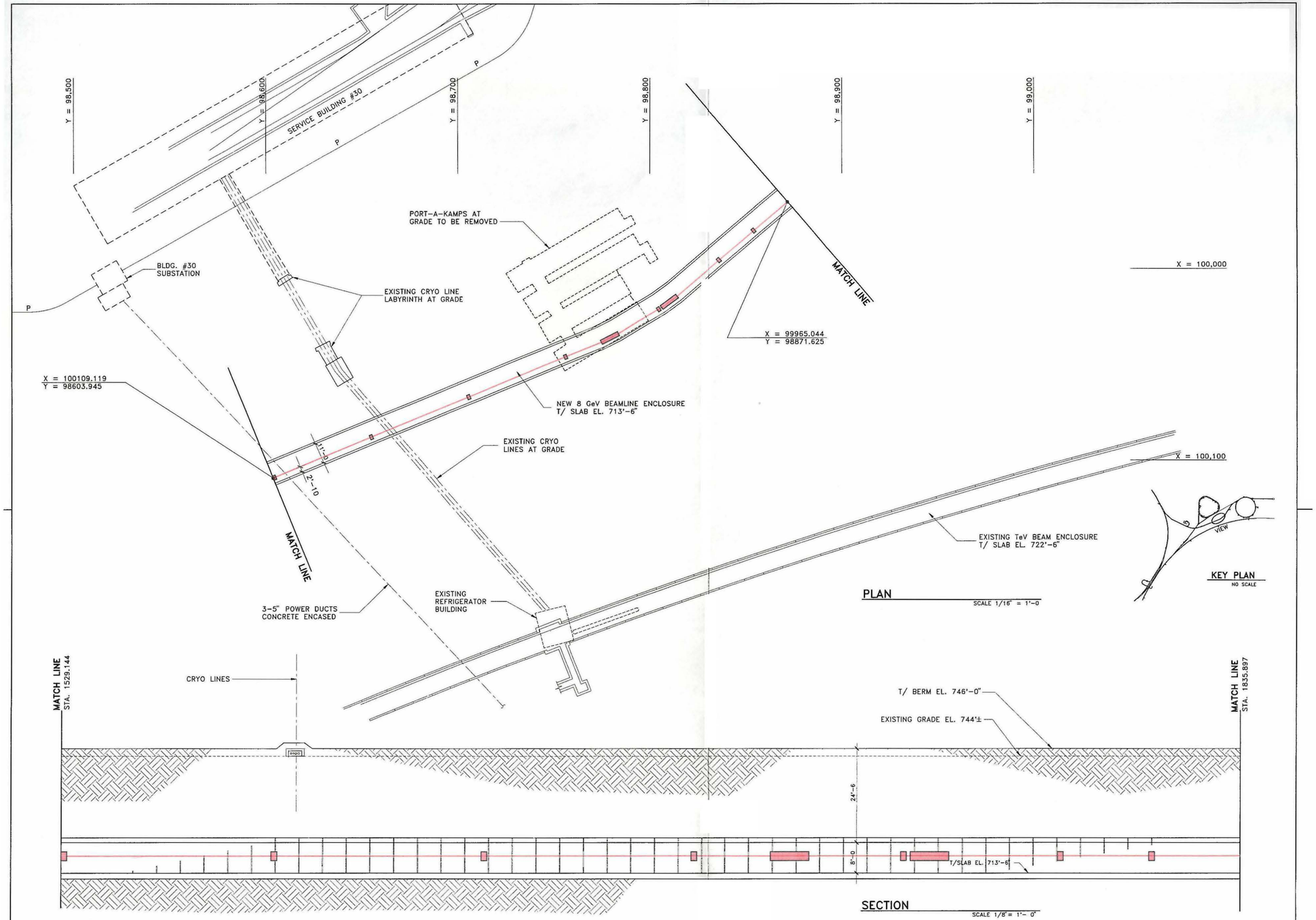
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
8 GeV BEAMLINE SHT. 2

DRAWING NO. 6-6-1 CDR-19 REV.

OCT. 1991

CDR-19



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	J. HACKEMER	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

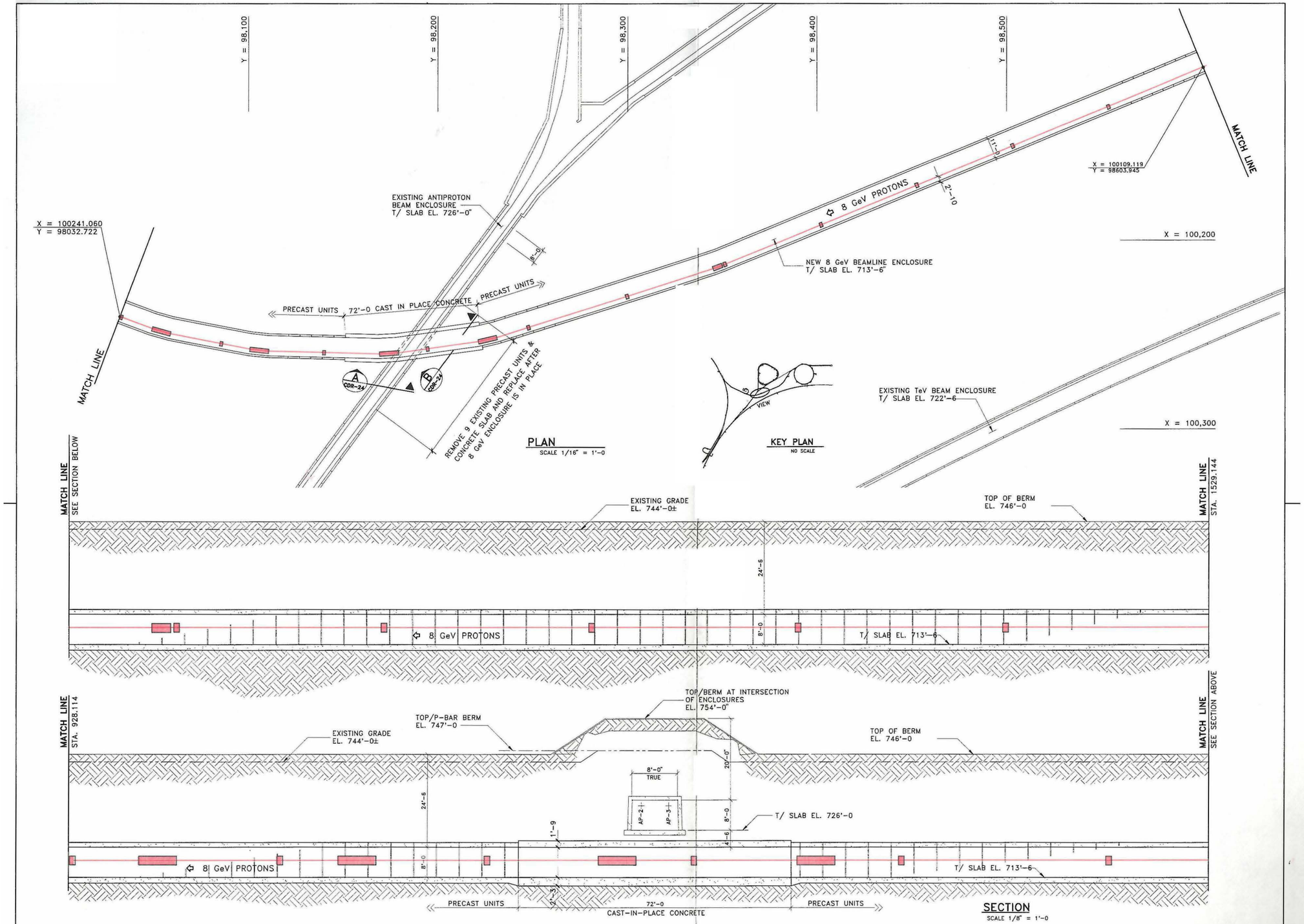
SCALE:
1/16"=1'-0" SCALE 8 0 8 16 24 32 40 FEET
PLAN SCALE
1/8"=1'-0" SCALE 8 0 8 16 FEET
SECTION SCALE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
8 GeV BEAMLINE SHT. 3

DRAWING NO. 6-6-1 CDR-20 REV.

OCT. 1991



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	J. HACKEMER	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1/16"=1'-0" PLAN SCALE
1/8"=1'-0" SECTION SCALE

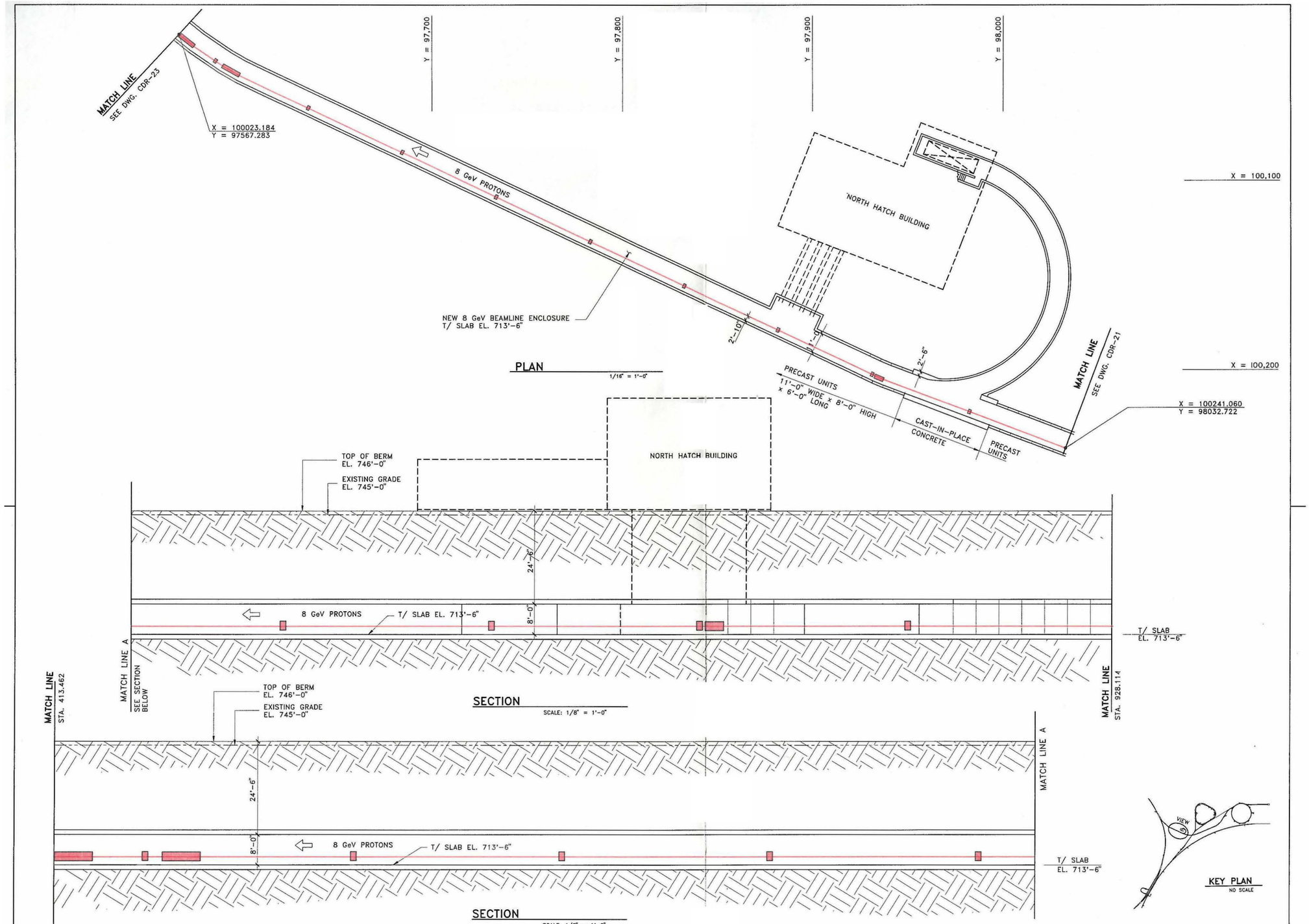
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
8 GeV BEAMLINE SHT. 4

DRAWING NO. 6-6-1 CDR-21 REV.

OCT. 1991

04-54-09p.m. 25OCT91



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	J. HACKEMER	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1/16"=1'-0" SCALE 8 0 8 16 24 32 40 FEET
PLAN SCALE
1/8"=1'-0" SCALE 8 0 8 16 FEET
SECTION SCALE

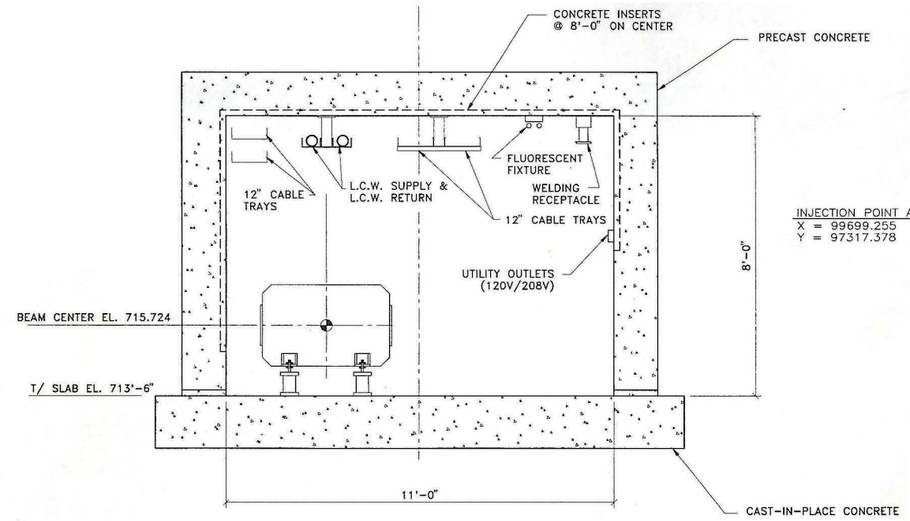
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
8 GeV BEAMLINE SHT. 5

DRAWING NO. 6-6-1 CDR-22 REV.

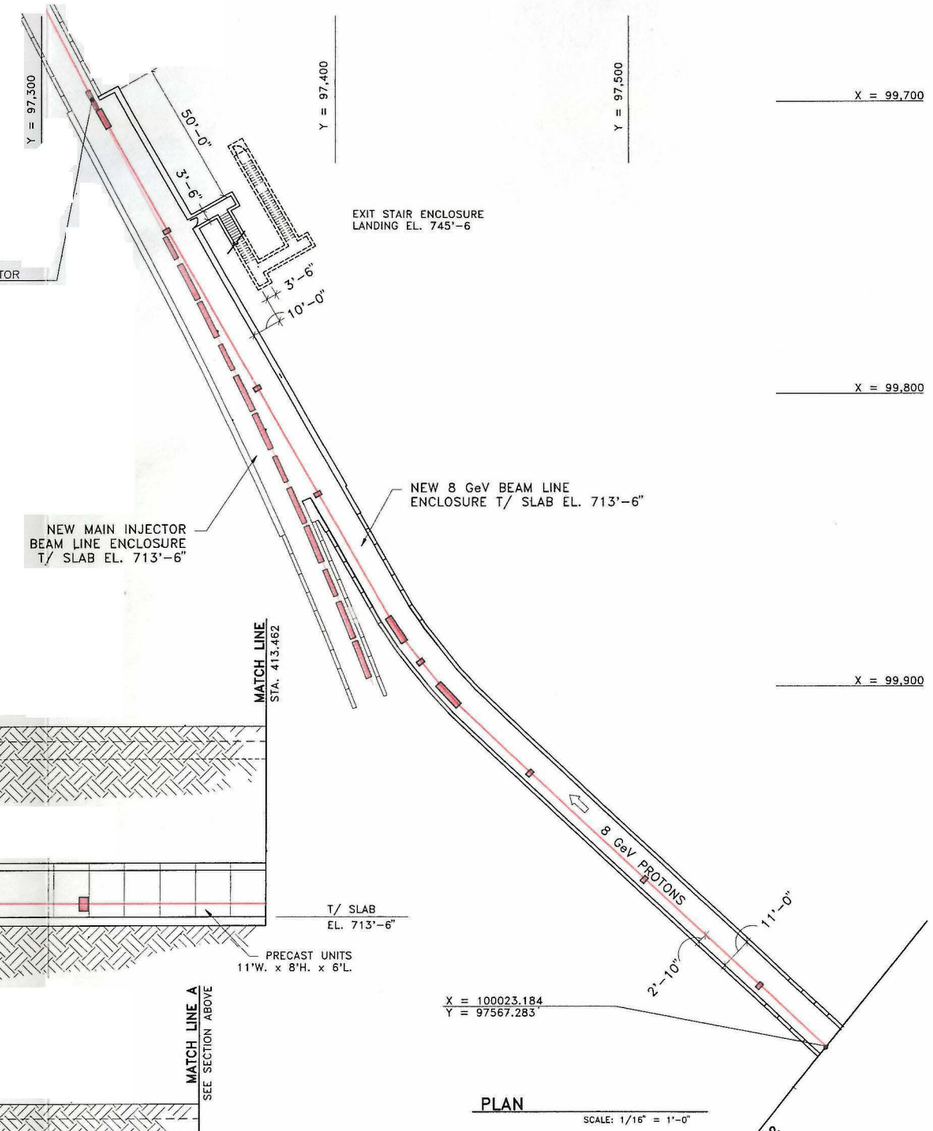
OCT. 1991

10-49386.m. 220C191



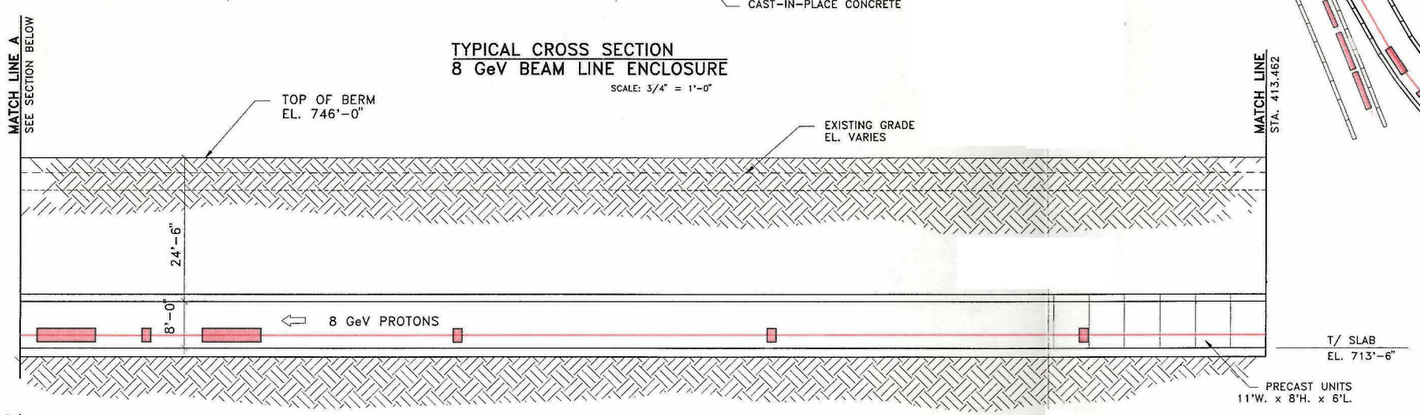
TYPICAL CROSS SECTION
8 GeV BEAM LINE ENCLOSURE

SCALE: 3/4" = 1'-0"



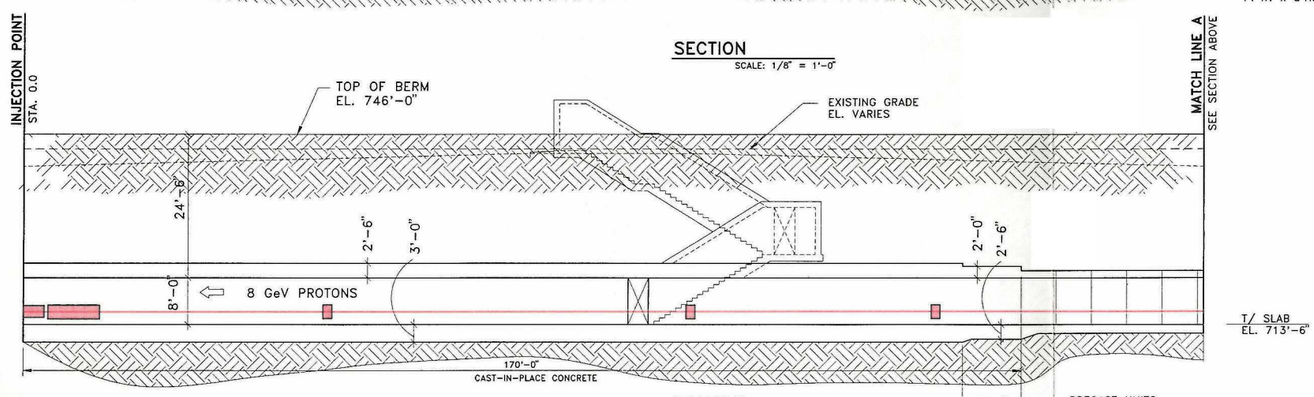
PLAN

SCALE: 1/16" = 1'-0"



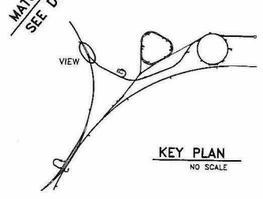
SECTION

SCALE: 1/8" = 1'-0"



SECTION

SCALE: 1/8" = 1'-0"



KEY PLAN

NO SCALE

REV.	DATE	DESCRIPTIONS

REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	J. HACKEMER	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

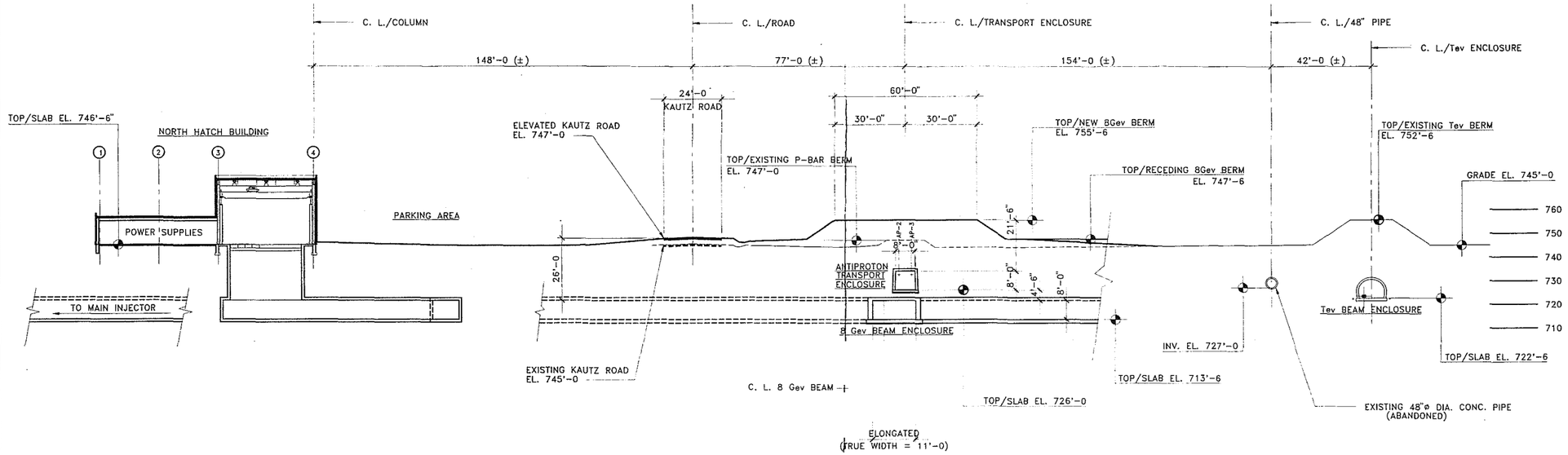
SCALE:
1/16"=1'-0" — PLAN SCALE
1/8"=1'-0" — SECTION SCALE
3/4"=1'-0" — SECTION SCALE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
8 GeV BEAMLINE SHT. 6

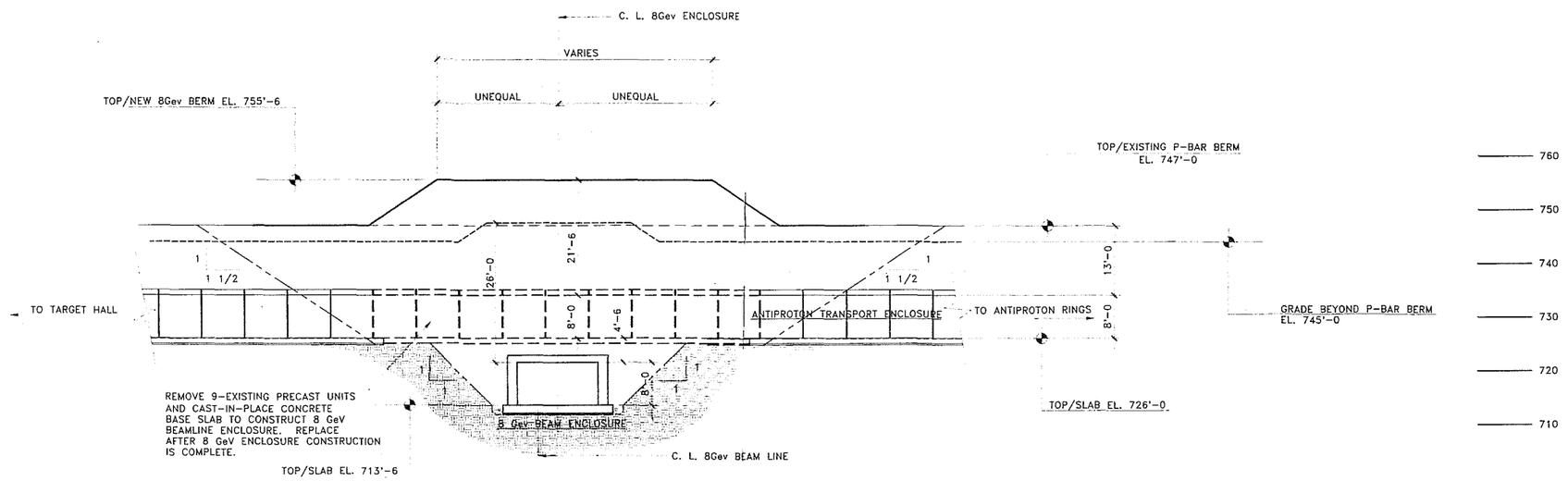
DRAWING NO. 6-6-1 CDR-23 REV.

OCT. 1991



SECTION ACROSS ANTIPROTON TRANSPORT ENCLOSURE LOOKING WEST (A / CDR-21)

SCALE 1/16" = 1'- 0"



SECTION ACROSS ANTIPROTON TRANSPORT ENCLOSURE LOOKING SOUTH (B / CDR-21)

SCALE 1/8" = 1'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI/J. HACKEMER	
DRAWN	J. HACKEMER	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:

1/16"=1'-0" 8 0 8 16 24 32 40 SCALE FEET — UPPER SECTION

1/8"=1'-0" 8 0 8 16 SCALE FEET — LOWER SECTION

FERMI NATIONAL ACCELERATOR LABORATORY

UNITED STATES DEPARTMENT OF ENERGY

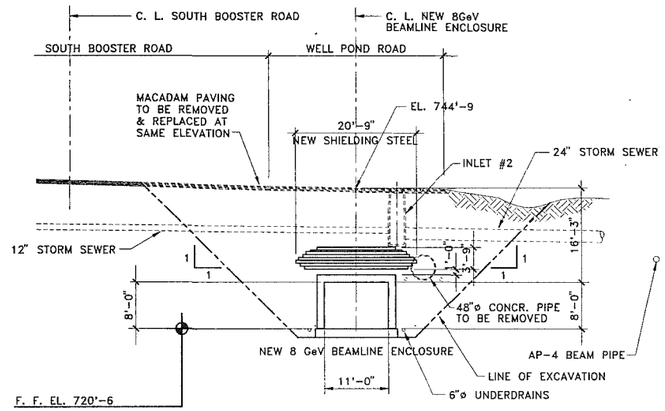
FERMILAB MAIN INJECTOR

8 GeV SECTIONS SHT. 1

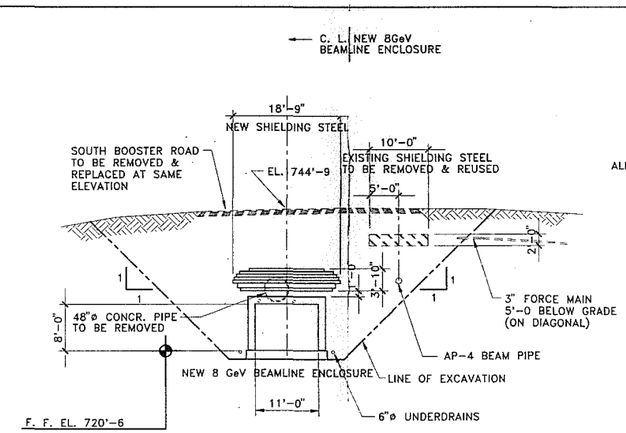
DRAWING NO. 6-6-1 CDR-24 REV.

OCT. 1991

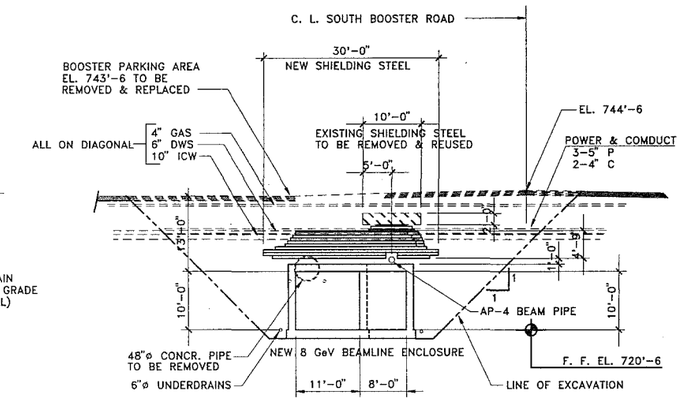
01:31:47a.m. 24OCT91



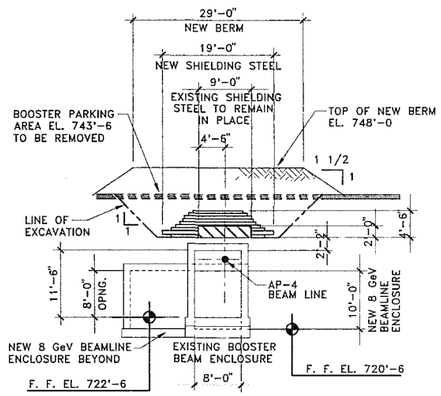
SECTION A 1/8"=1'-0" CDR-18



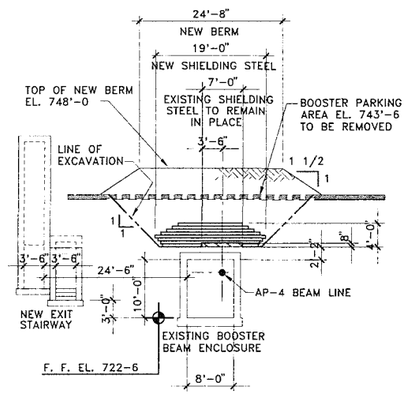
SECTION B 1/8"=1'-0" CDR-18



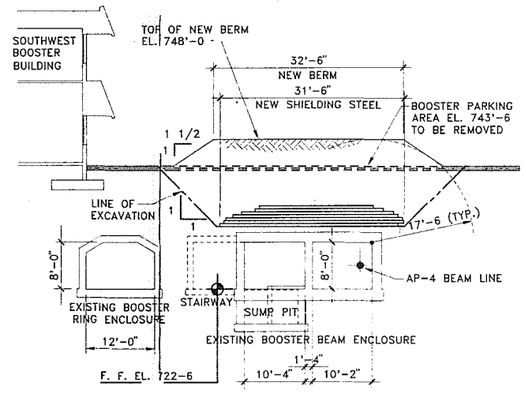
SECTION C 1/8"=1'-0" CDR-18



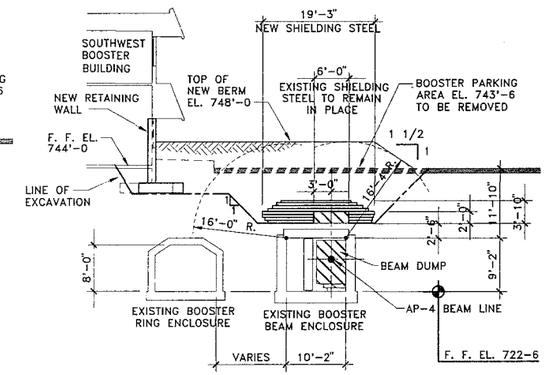
SECTION D 1/8"=1'-0" CDR-18



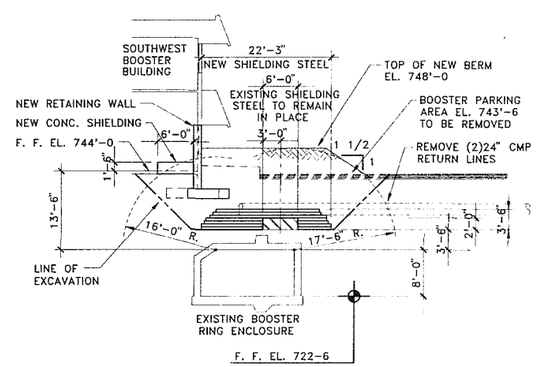
SECTION E 1/8"=1'-0" CDR-18



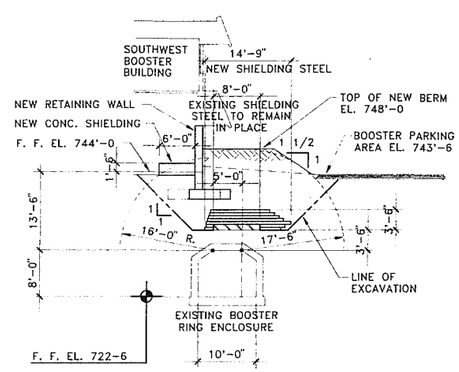
SECTION F 1/8"=1'-0" CDR-18



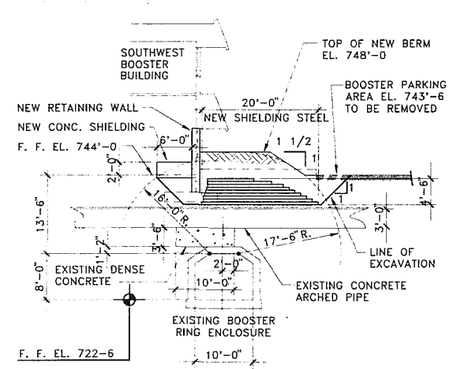
SECTION G 1/8"=1'-0" CDR-18



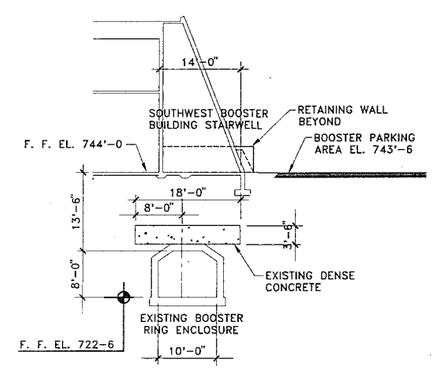
SECTION H 1/8"=1'-0" CDR-18



SECTION J 1/8"=1'-0" CDR-18



SECTION K 1/8"=1'-0" CDR-18



SECTION M 1/8"=1'-0" CDR-18

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	J. HACKEMER J. GEHARD	
CHECKED		
APPROVED		
SUBMITTED		

SCALE: 1/8"=1'-0" 8 0 8 16 SCALE FEET

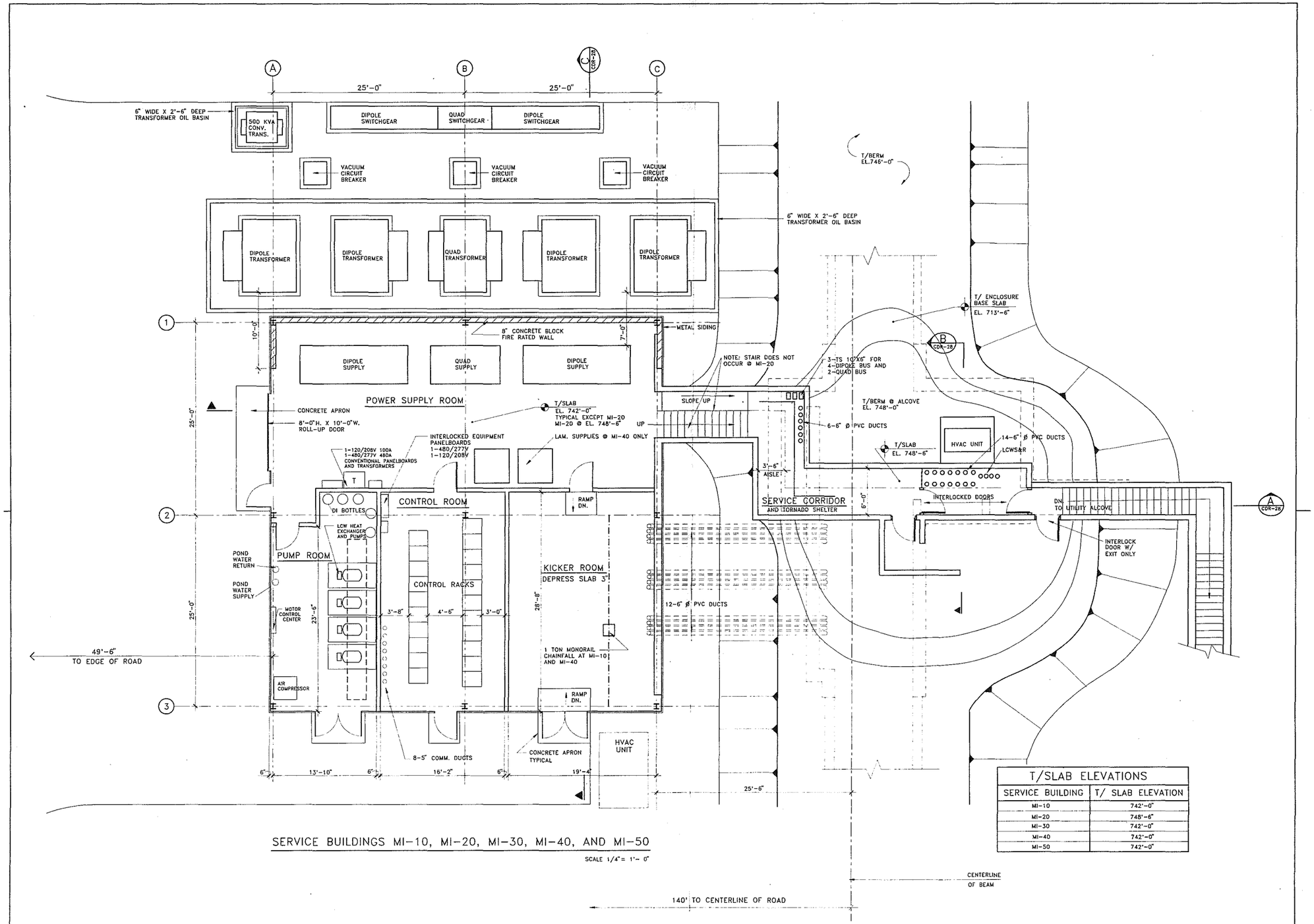
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
8 GeV SECTIONS SHT. 2

DRAWING NO. 6-6-1 CDR-25 REV.

OCT. 1991

02-2506a.m. 250C191



SERVICE BUILDINGS MI-10, MI-20, MI-30, MI-40, AND MI-50

SCALE 1/4" = 1'- 0"

T/SLAB ELEVATIONS

SERVICE BUILDING	T/ SLAB ELEVATION
MI-10	742'-0"
MI-20	748'-6"
MI-30	742'-0"
MI-40	742'-0"
MI-50	742'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI/L. JENKINS	
CHECKED		
APPROVED		
SUBMITTED		

SCALE: 1/4"=1'-0" (4 0 4 8 SCALE FEET)

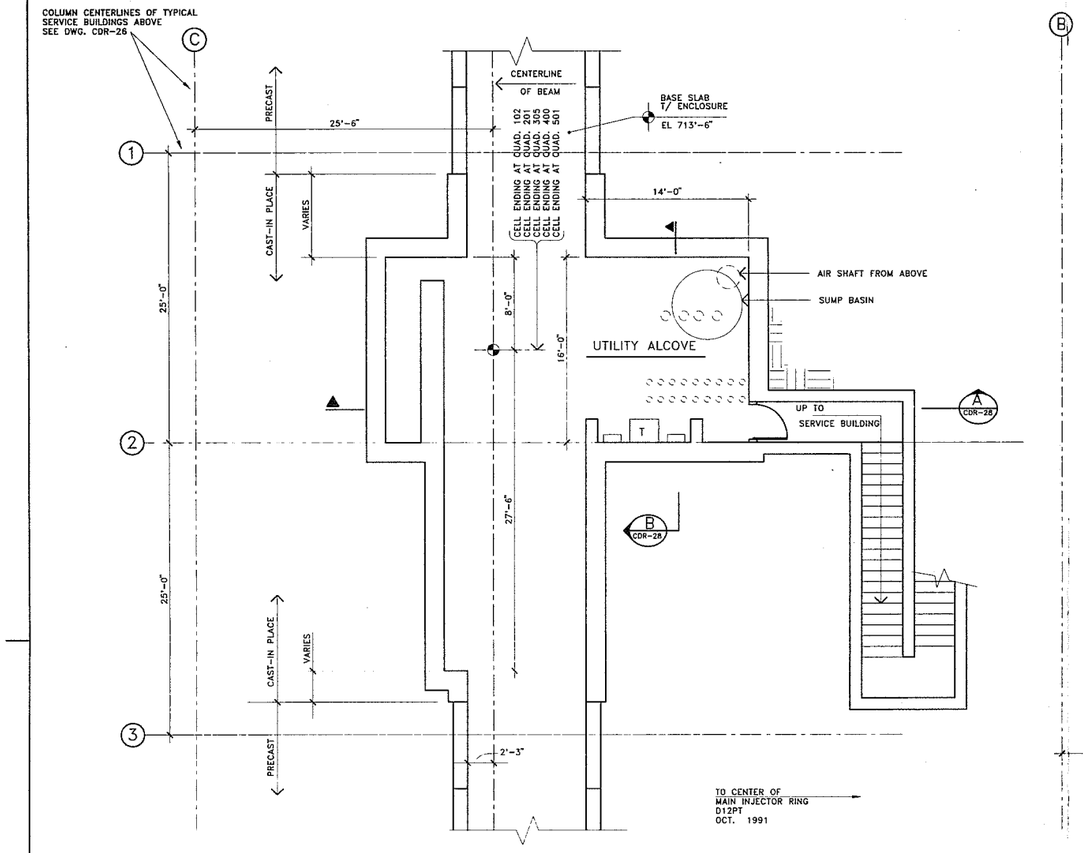
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
TYPICAL SERVICE BUILDING PLAN

DRAWING NO. 6-6-1 CDR-26 REV.

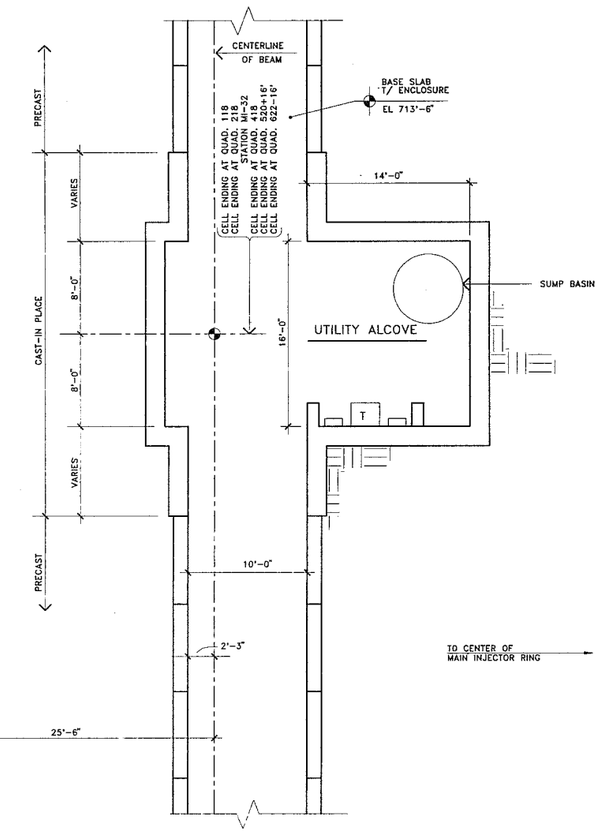
OCT. 1991

CDR-26



ALCOVE PLAN AT TYPICAL SERVICE BUILDINGS

1/4" = 1'-0"



ALCOVE PLAN AT KICKER BUILDINGS
AND BETWEEN TYPICAL SERVICE BUILDINGS

1/4" = 1'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	TOMSKI	
DRAWN	TOMSKI	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:
1/4"=1'-0" SCALE 0 4 8 FEET

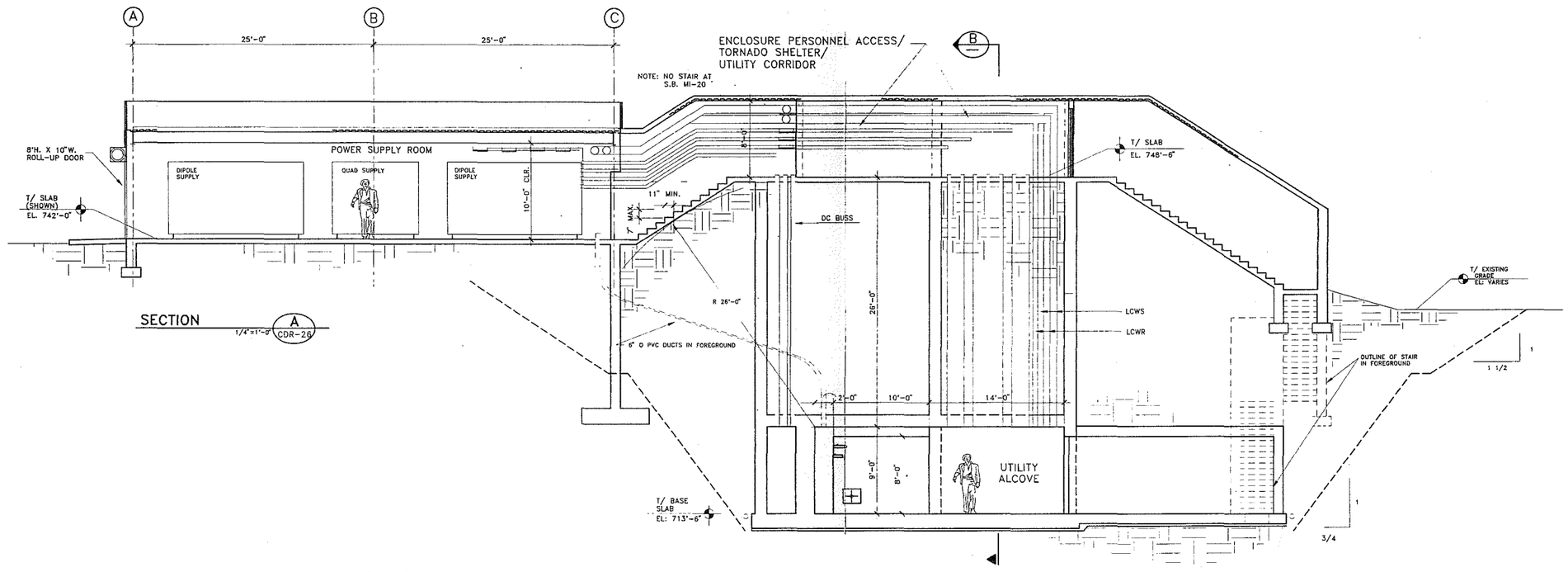
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
ALCOVE PLANS

DRAWING NO. 6-6-1 CDR-27 REV.

OCT. 1991

09:41:05a.m. 22OCT91



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI/L. JENKINS	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:
1/4"=1'-0" 4 0 4 8 SCALE FEET

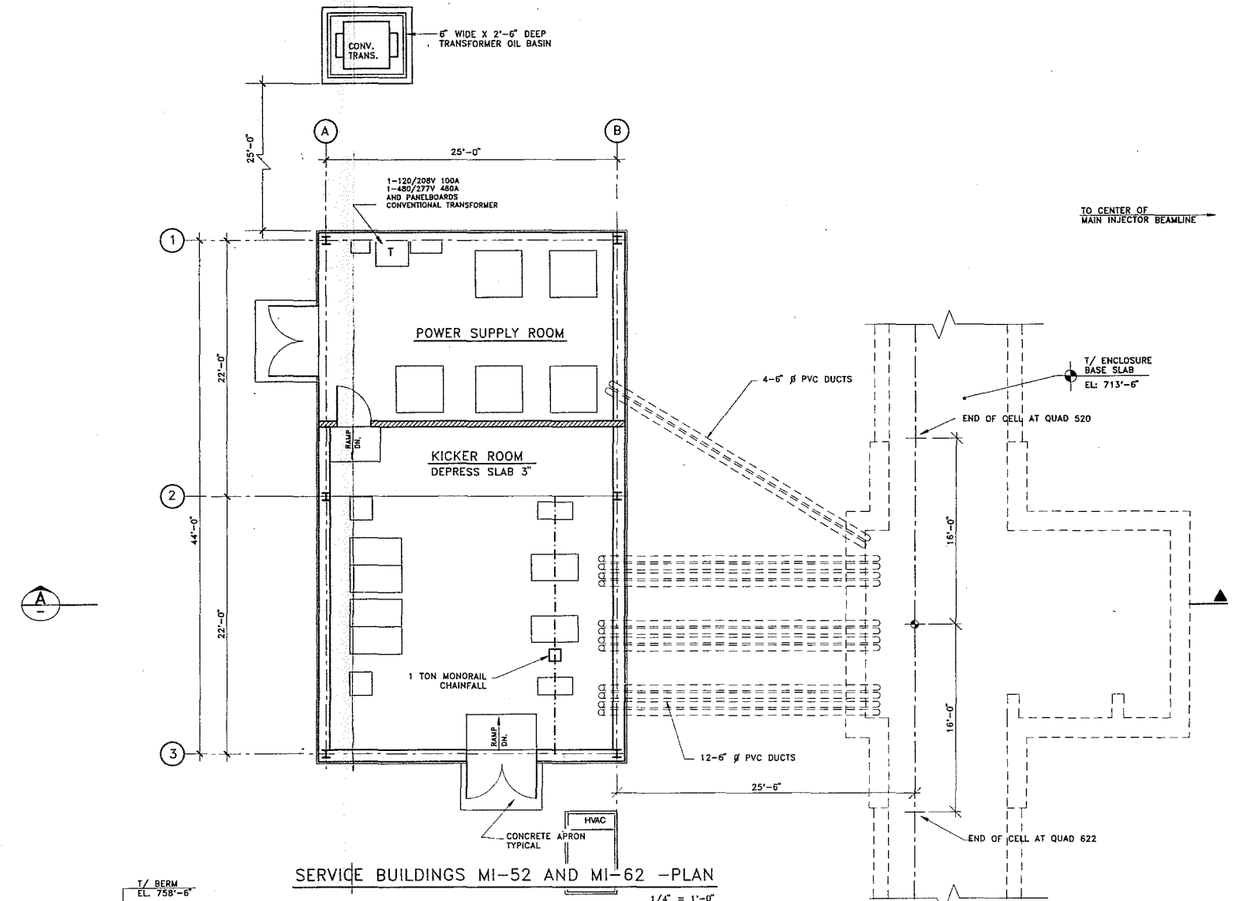
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
SERVICE BUILDING SECTION

DRAWING NO 6-6-1 CDR-28 REV.

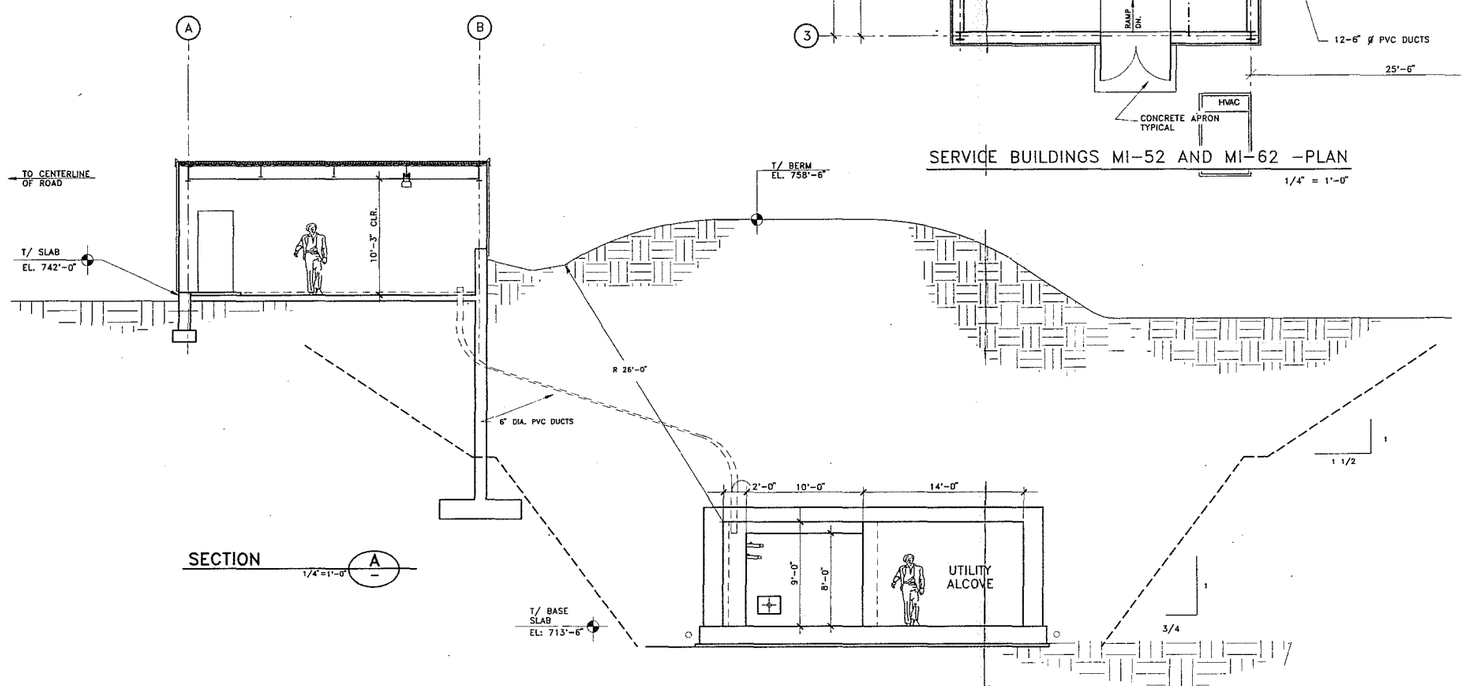
OCT. 1991

09:21:53a.m. 28OCT91



SERVICE BUILDINGS MI-52 AND MI-62 -PLAN

1/4" = 1'-0"



SECTION A

1/4"=1'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	TOMSKI	
DRAWN	TOMSKI	
CHECKED		
APPROVED		
SUBMITTED		

SCALE: 1/4"=1'-0" (4 0 4 8 SCALE FEET)

FERMI NATIONAL ACCELERATOR LABORATORY

UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR

KICKER SERVICE BUILDING

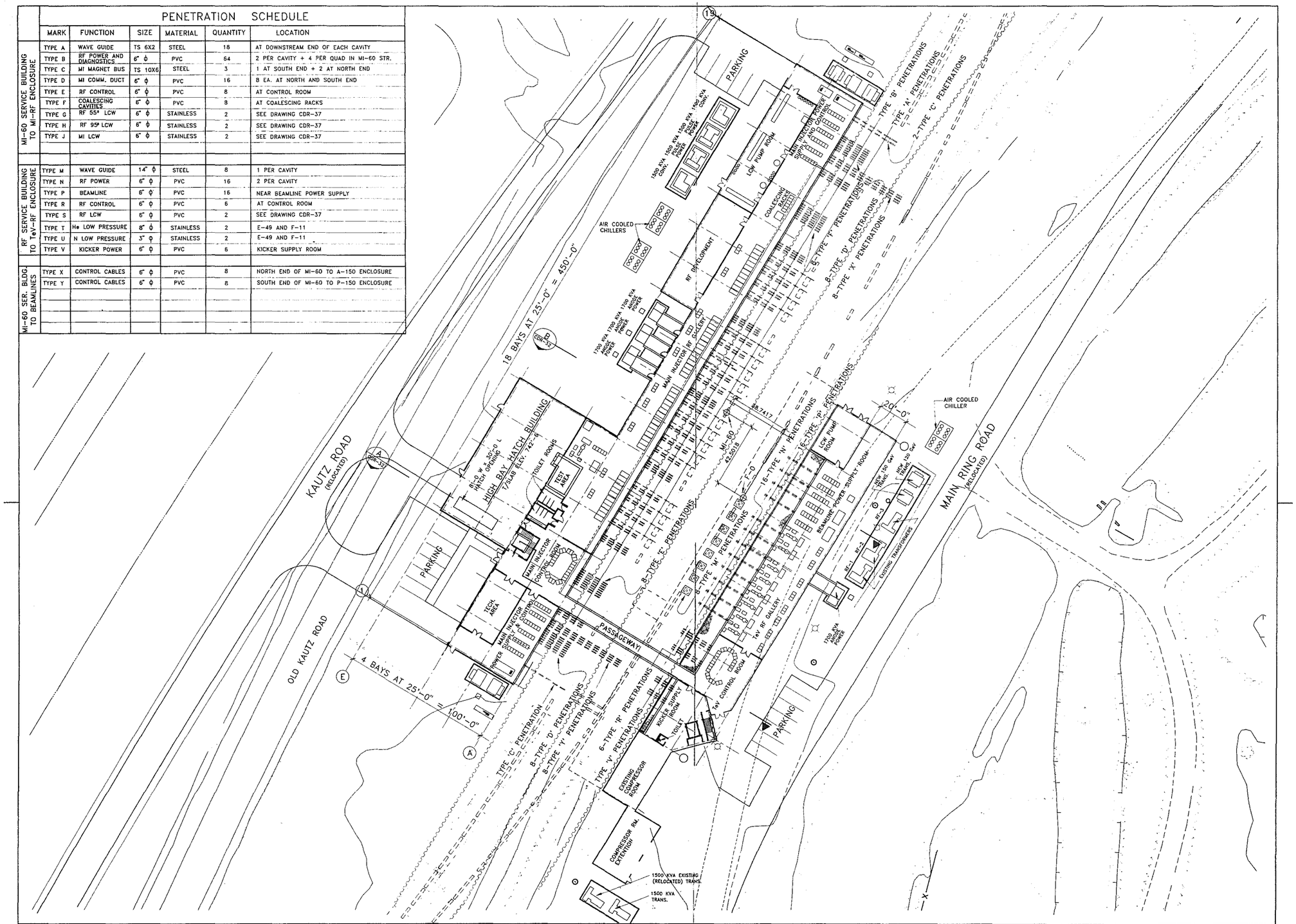
DRAWING NO. 6-6-1 CDR-29 REV.

OCT. 1996

09:54:46 a.m. 2/30/191

PENETRATION SCHEDULE

	MARK	FUNCTION	SIZE	MATERIAL	QUANTITY	LOCATION
MI-60 SERVICE BUILDING TO MI-RF ENCLOSURE	TYPE A	WAVE GUIDE	TS 6X2	STEEL	18	AT DOWNSTREAM END OF EACH CAVITY
	TYPE B	RF POWER AND DIAGNOSTICS	6" ϕ	PVC	64	2 PER CAVITY + 4 PER QUAD IN MI-60 STR.
	TYPE C	MI MAGNET BUS	TS 10X6	STEEL	3	1 AT SOUTH END + 2 AT NORTH END
	TYPE D	MI COMM. DUCT	6" ϕ	PVC	16	8 EA. AT NORTH AND SOUTH END
	TYPE E	RF CONTROL	6" ϕ	PVC	8	AT CONTROL ROOM
	TYPE F	COALESCING CAVITIES	6" ϕ	PVC	8	AT COALESCING RACKS
	TYPE G	RF 55° LCW	6" ϕ	STAINLESS	2	SEE DRAWING CDR-37
	TYPE H	RF 95° LCW	6" ϕ	STAINLESS	2	SEE DRAWING CDR-37
	TYPE J	MI LCW	6" ϕ	STAINLESS	2	SEE DRAWING CDR-37
RF SERVICE BUILDING TO Tev-RF ENCLOSURE	TYPE M	WAVE GUIDE	14" ϕ	STEEL	8	1 PER CAVITY
	TYPE N	RF POWER	6" ϕ	PVC	16	2 PER CAVITY
	TYPE P	BEAMLINE	6" ϕ	PVC	16	NEAR BEAMLINE POWER SUPPLY
	TYPE R	RF CONTROL	6" ϕ	PVC	6	AT CONTROL ROOM
	TYPE S	RF LCW	6" ϕ	PVC	2	SEE DRAWING CDR-37
	TYPE T	He LOW PRESSURE	8" ϕ	STAINLESS	2	E-49 AND F-11
	TYPE U	N LOW PRESSURE	3" ϕ	STAINLESS	2	E-49 AND F-11
	TYPE V	KICKER POWER	6" ϕ	PVC	6	KICKER SUPPLY ROOM
MI-60 SER. BLDG. TO BEAMLINES	TYPE X	CONTROL CABLES	6" ϕ	PVC	8	NORTH END OF MI-60 TO A-150 ENCLOSURE
	TYPE Y	CONTROL CABLES	6" ϕ	PVC	8	SOUTH END OF MI-60 TO P-150 ENCLOSURE



REV.	DATE	DESCRIPTIONS REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	T. LACKOWSKI/T. BURKE	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 20'-0" (20 0 20 40 SCALE FEET)

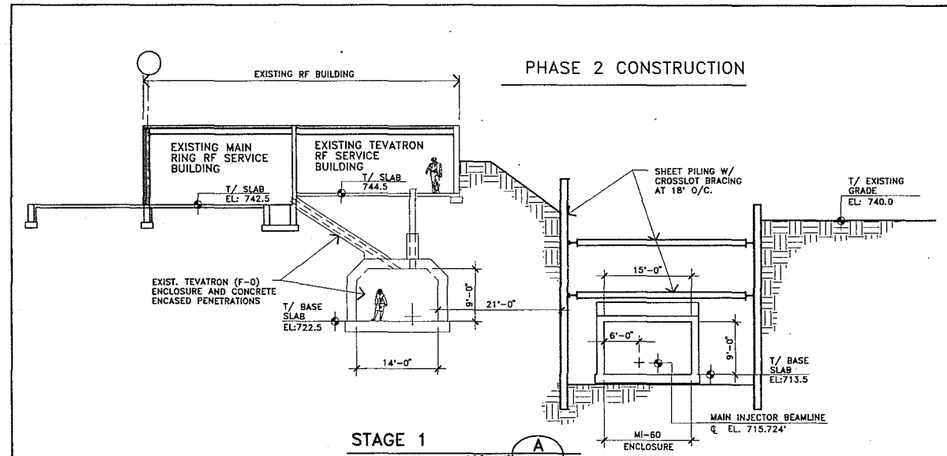
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

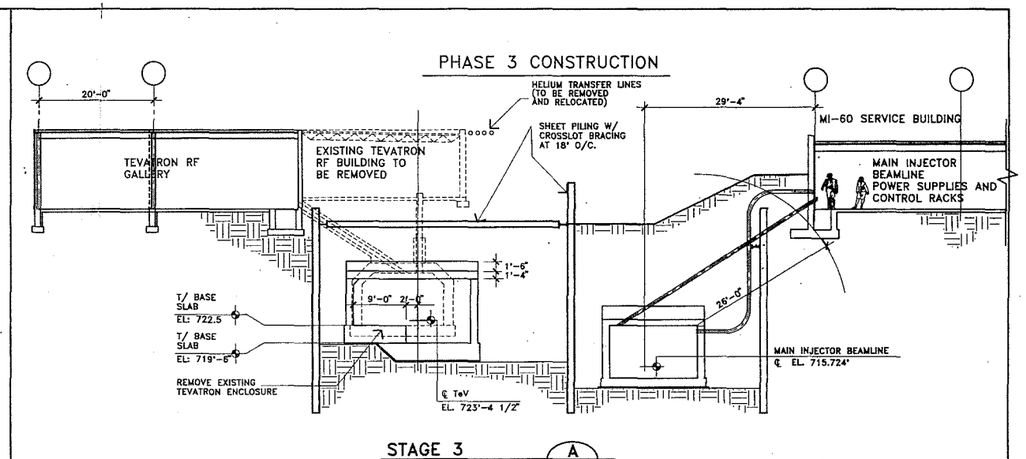
FERMILAB MAIN INJECTOR
F-0 / MI-60 PLAN

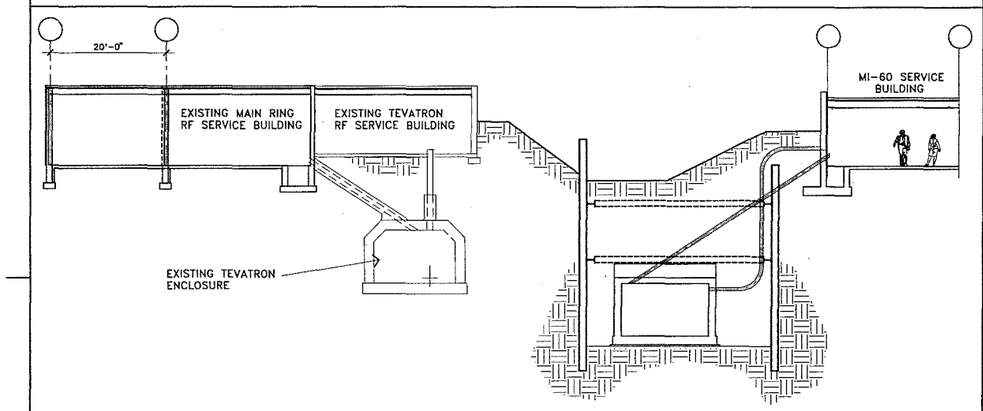
DRAWING NO. 6-6-1 CDR-30 REV.

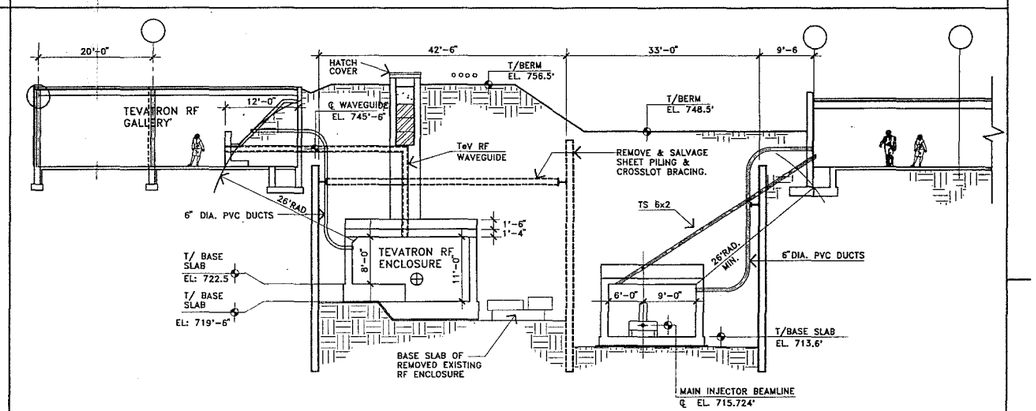
OCT. 1991

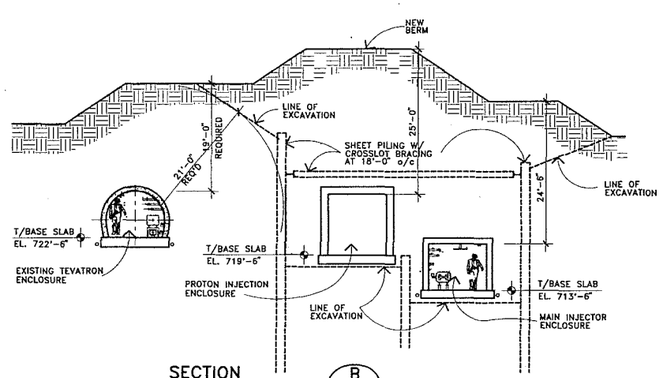
03.58:05p.m. 17DEC91

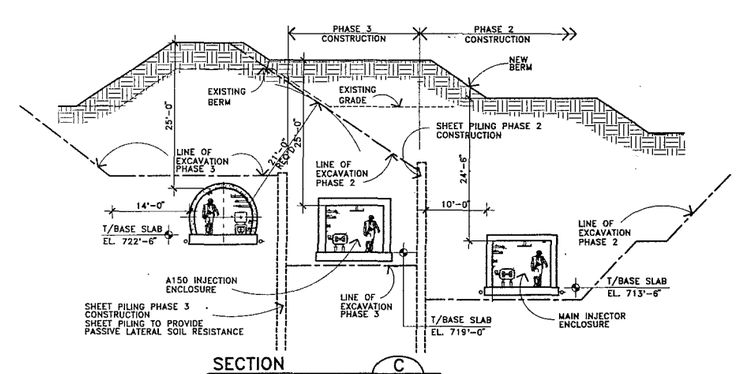












REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	TOMSKI	
DRAWN	TOMSKI	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:
1/8"=1'-0" 8 0 8 16 SCALE FEET

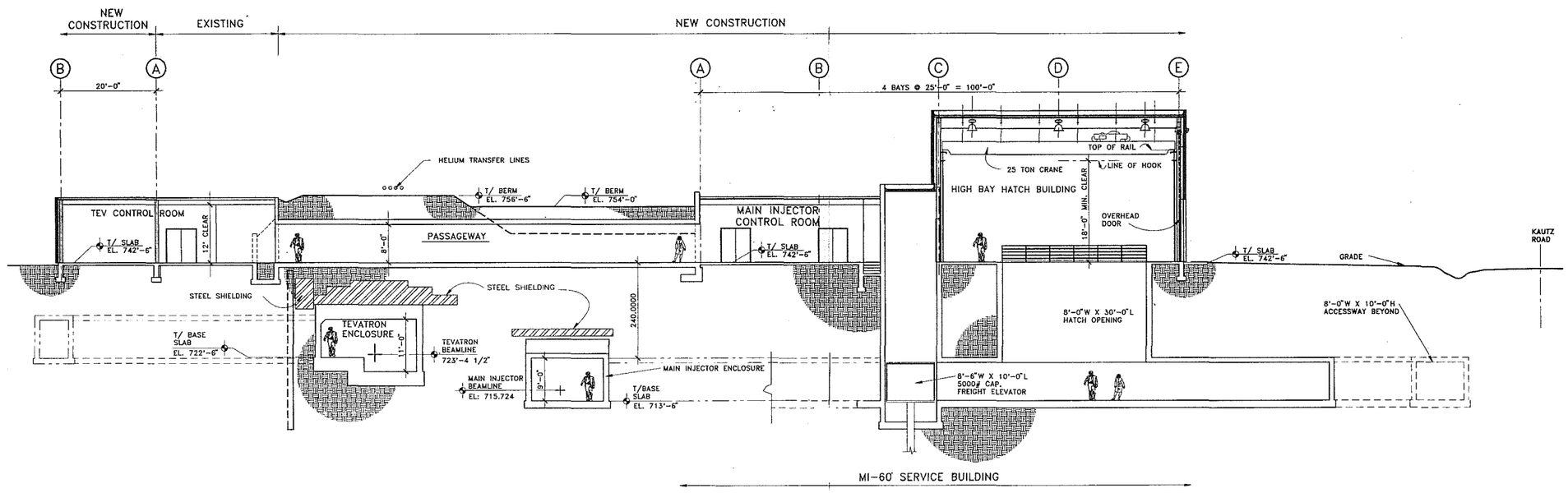
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
MI-60 CONSTRUCTION SECTIONS

DRAWING NO. 6-6-1 CDR-31 REV.

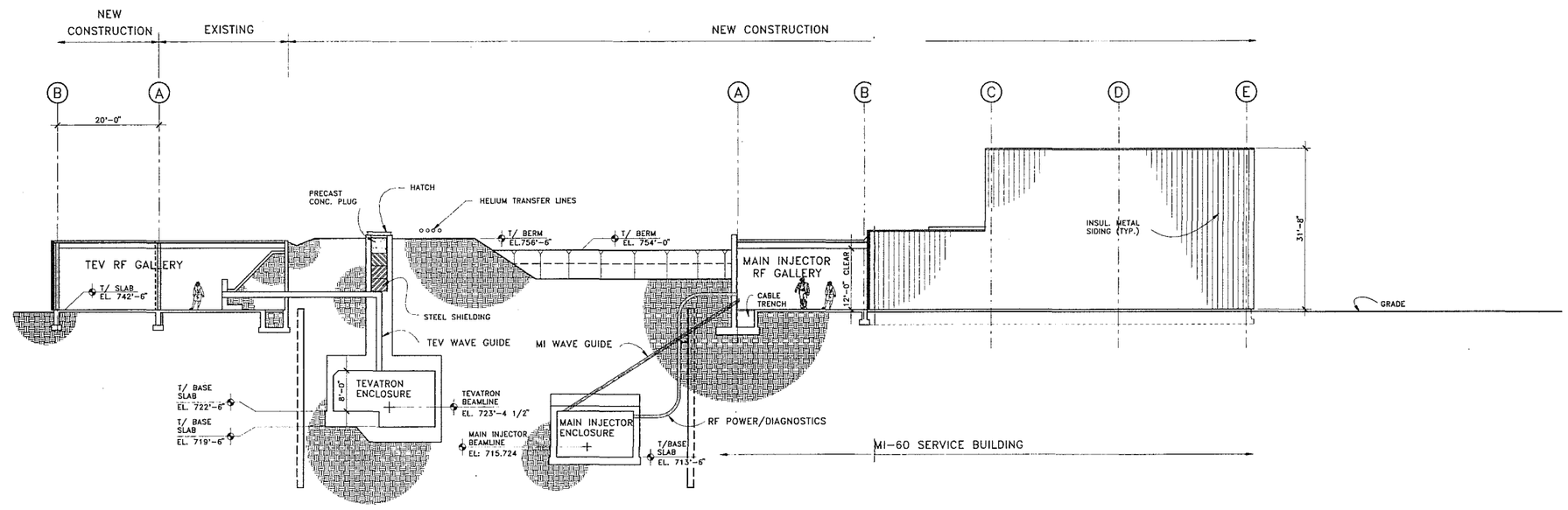
OCT. 1991

08:34:40a.m. 25OCT91



SECTION A CDR-30

SCALE 1/8" = 1'-0"



SECTION B CDR-30

SCALE 1/8" = 1'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	T. LACKOWSKI	
DRAWN	J. BANKS/L. JENKINS	
CHECKED		
APPROVED		
SUBMITTED		

SCALE: 1/8"=1'-0" 4 0 4 8 12 16 20 SCALE FEET

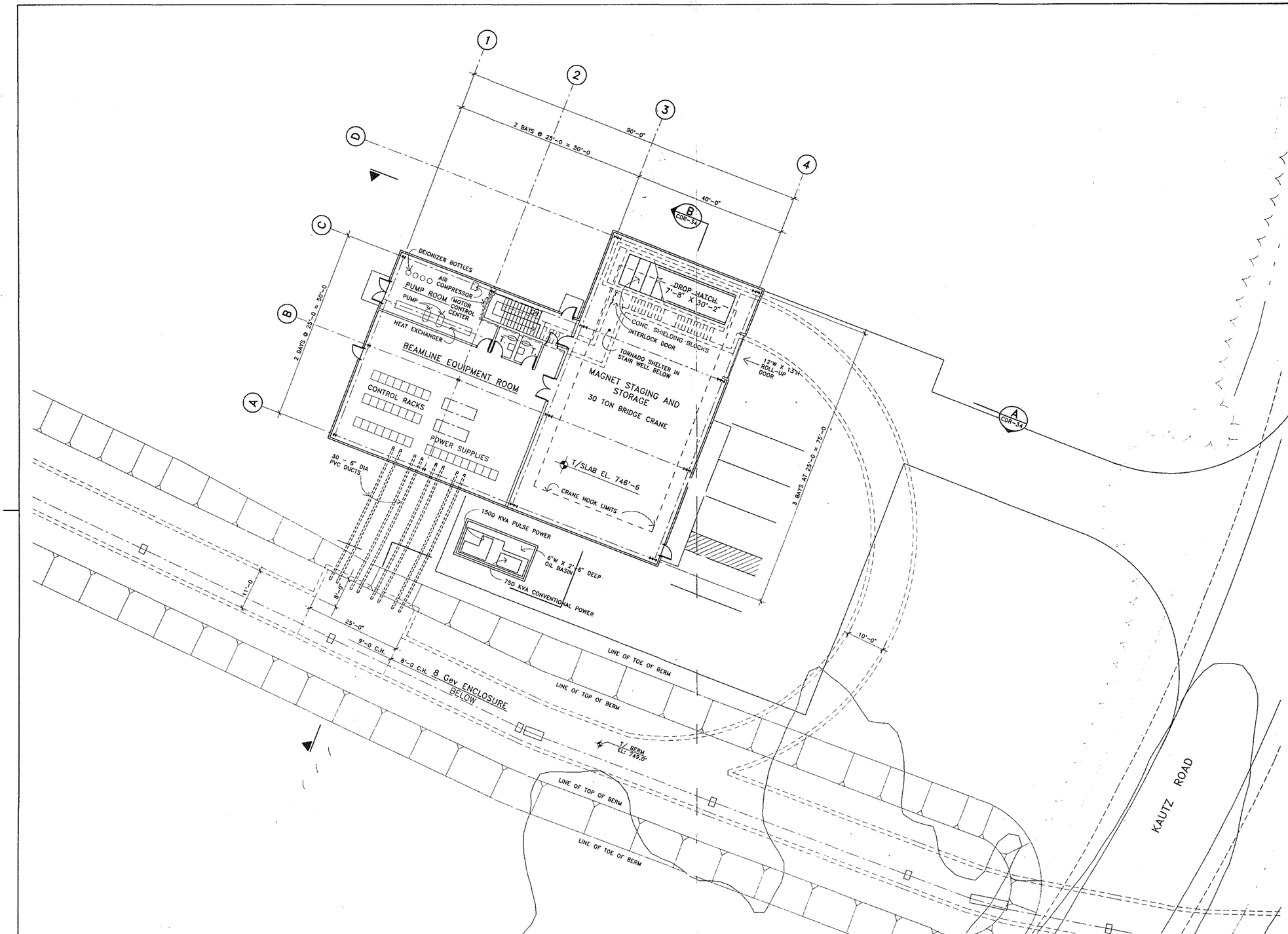
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
MI-60 BUILDING SECTIONS

DRAWING NO. 6-6-1 CDR-32 REV.

OCT. 1991

11:31:45a.m. 28OCT91



REV.	DATE	DESCRIPTIONS REVISIONS

	NAME	DATE
DESIGNED	TOMSKI	
DRAWN	T.BURKE,J.W.B.	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1/8"=1'-0"

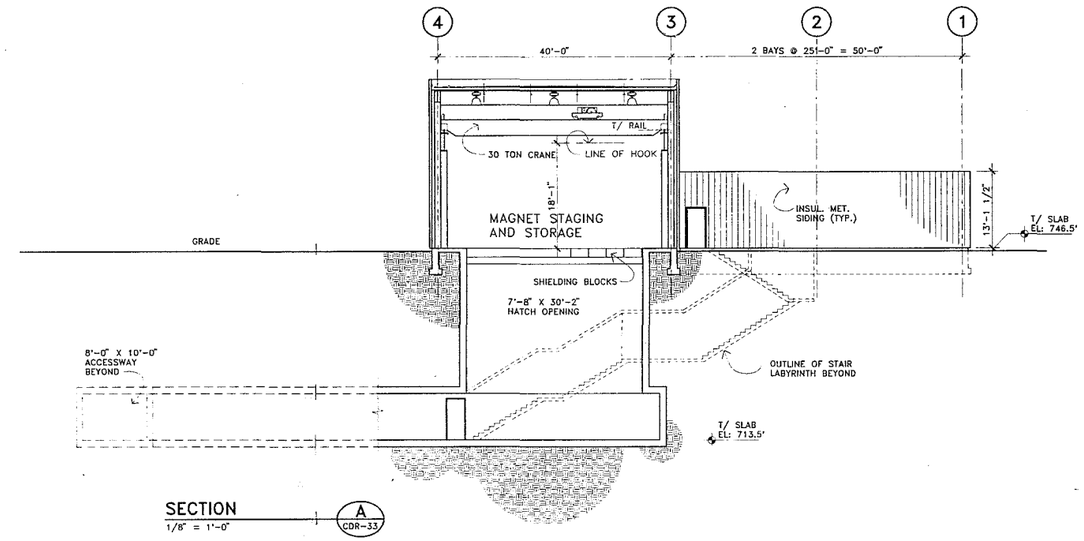
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
NORTH HATCH BUILDING PLAN

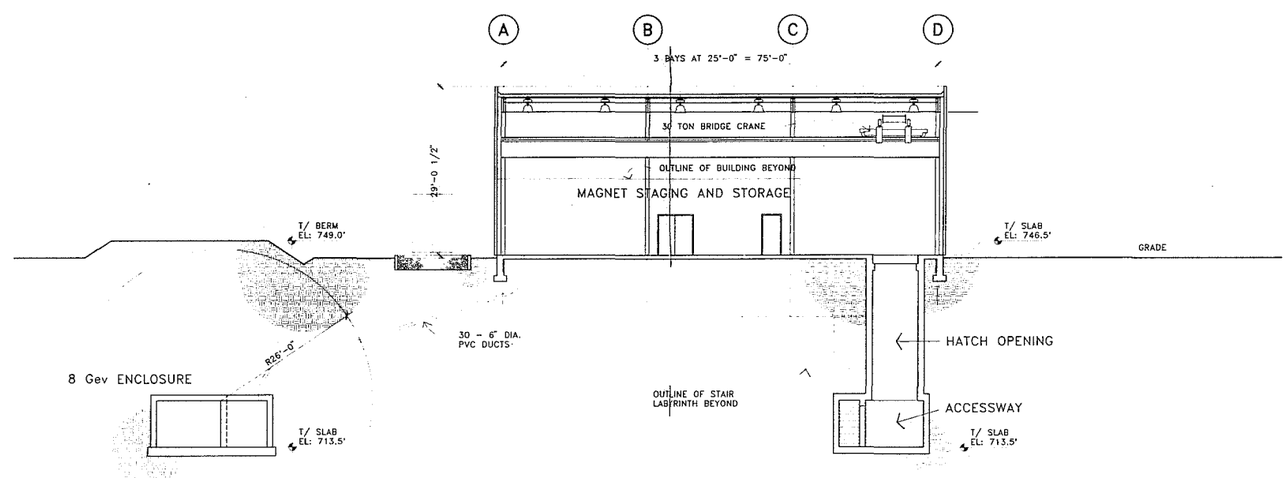
DRAWING NO. 6-6-1 CDR-33 REV.

OCT. 1991

05-17-54p.m. 24OCT91



SECTION A CDR-33
1/8" = 1'-0"



SECTION B CDR-33
1/8" = 1'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	TOMSKI	
DRAWN	T. BURKE, J.W.B.	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:
1/8"=1'-0" 8 0 8 16 SCALE FEET

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

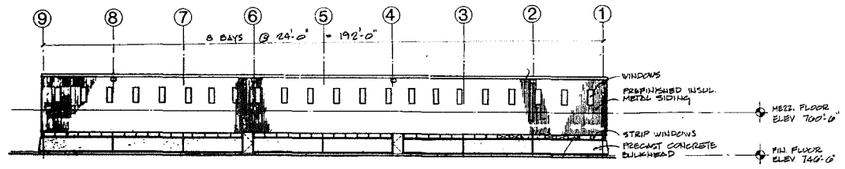
FERMILAB MAIN INJECTOR
NORTH HATCH BUILDING SECTIONS

DRAWING NO. 6-6-1 CDR-34 REV.

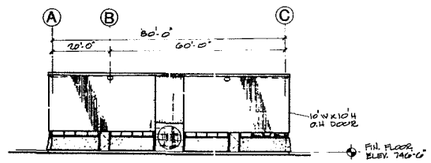
OCT. 1991

05:21:26p.m. 24OCT91

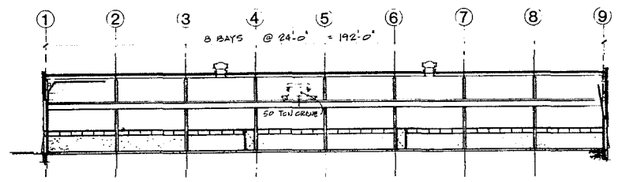
CDR-34



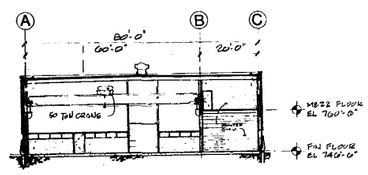
NORTH ELEVATION
1/16" = 1'-0"



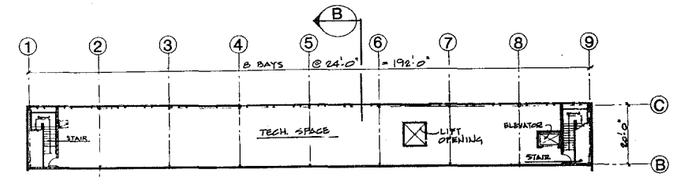
WEST ELEVATION
1/16" = 1'-0"



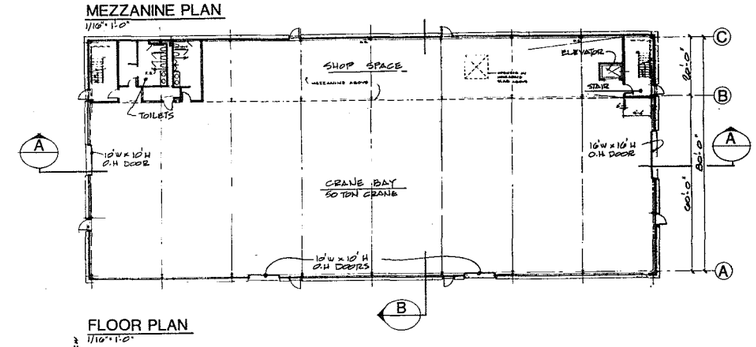
SECTION A-A
1/16" = 1'-0"



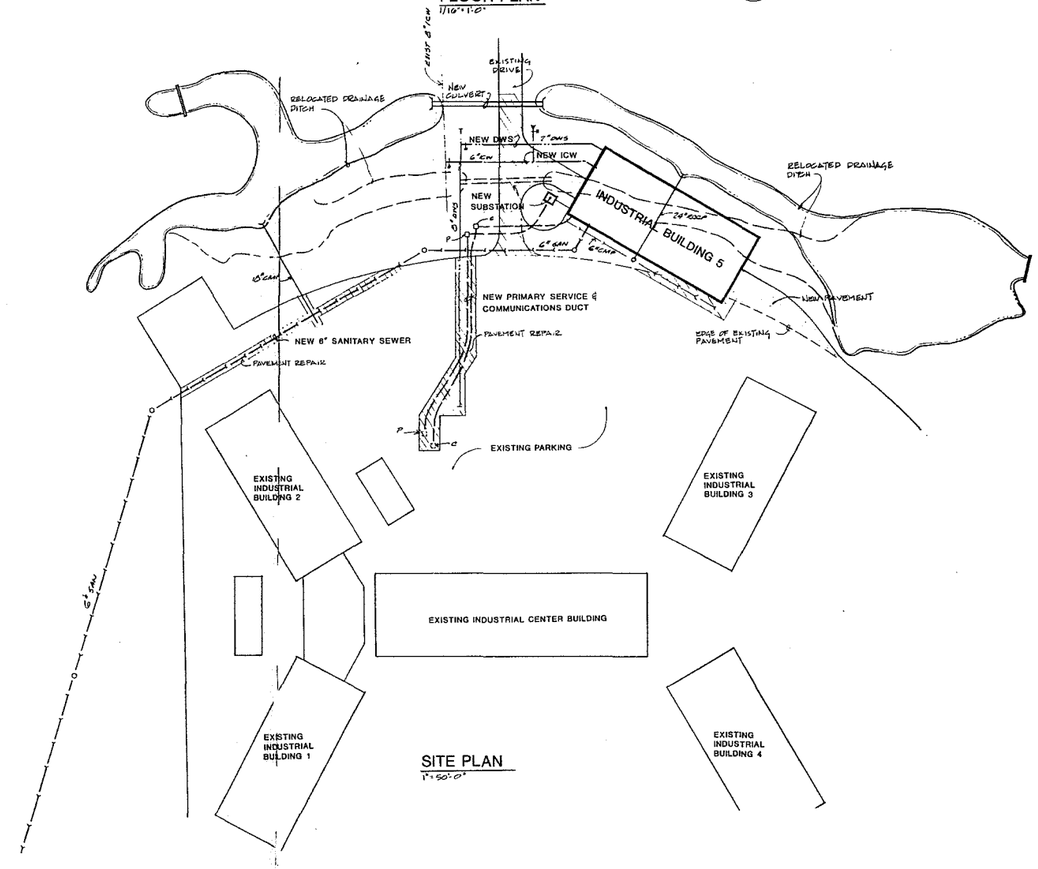
SECTION B-B
1/16" = 1'-0"



MEZZANINE PLAN
1/16" = 1'-0"



FLOOR PLAN
1/16" = 1'-0"



SITE PLAN
1" = 50'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	MIKE GRIMSON	
DRAWN	DICK KILLIAN	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

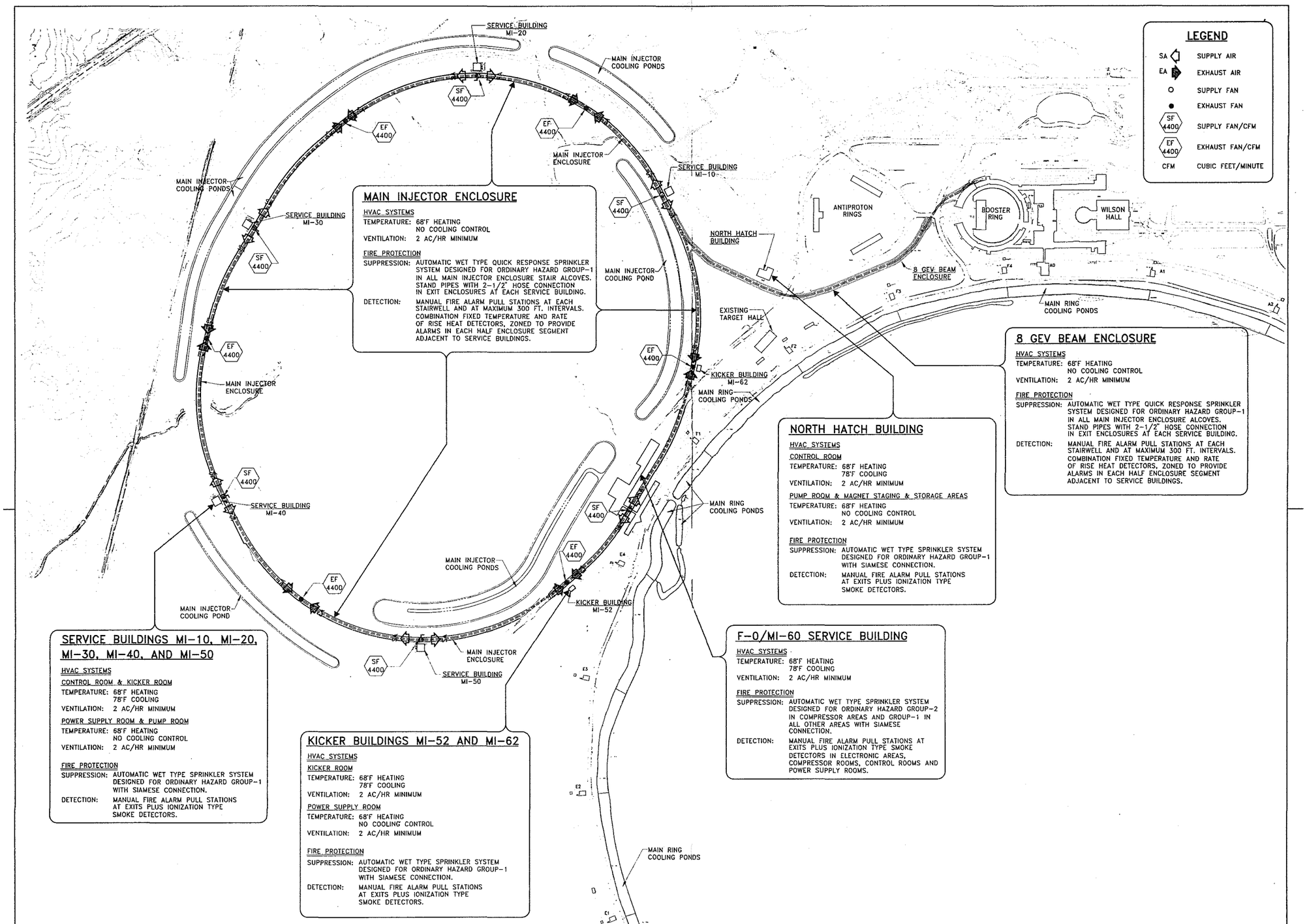
SCALE:
1/16" = 1'-0" Scale 8 0 8 16 32 Feet
1/50 = 1'-0" Scale 50 0 50 100 Feet

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
INDUSTRIAL BUIJLDING NO.5

DRAWING NO. 6-6-1 CDR-35 REV.

OCT. 1981



MAIN INJECTOR ENCLOSURE

HVAC SYSTEMS

TEMPERATURE: 68°F HEATING
NO COOLING CONTROL

VENTILATION: 2 AC/HR MINIMUM

FIRE PROTECTION

SUPPRESSION: AUTOMATIC WET TYPE QUICK RESPONSE SPRINKLER SYSTEM DESIGNED FOR ORDINARY HAZARD GROUP-1 IN ALL MAIN INJECTOR ENCLOSURE STAIR ALCOVES. STAND PIPES WITH 2-1/2" HOSE CONNECTION IN EXIT ENCLOSURES AT EACH SERVICE BUILDING.

DETECTION: MANUAL FIRE ALARM PULL STATIONS AT EACH STAIRWELL AND AT MAXIMUM 300 FT. INTERVALS. COMBINATION FIXED TEMPERATURE AND RATE OF RISE HEAT DETECTORS, ZONED TO PROVIDE ALARMS IN EACH HALF ENCLOSURE SEGMENT ADJACENT TO SERVICE BUILDINGS.

8 GEV BEAM ENCLOSURE

HVAC SYSTEMS

TEMPERATURE: 68°F HEATING
NO COOLING CONTROL

VENTILATION: 2 AC/HR MINIMUM

FIRE PROTECTION

SUPPRESSION: AUTOMATIC WET TYPE QUICK RESPONSE SPRINKLER SYSTEM DESIGNED FOR ORDINARY HAZARD GROUP-1 IN ALL MAIN INJECTOR ENCLOSURE ALCOVES. STAND PIPES WITH 2-1/2" HOSE CONNECTION IN EXIT ENCLOSURES AT EACH SERVICE BUILDING.

DETECTION: MANUAL FIRE ALARM PULL STATIONS AT EACH STAIRWELL AND AT MAXIMUM 300 FT. INTERVALS. COMBINATION FIXED TEMPERATURE AND RATE OF RISE HEAT DETECTORS, ZONED TO PROVIDE ALARMS IN EACH HALF ENCLOSURE SEGMENT ADJACENT TO SERVICE BUILDINGS.

NORTH HATCH BUILDING

HVAC SYSTEMS

CONTROL ROOM

TEMPERATURE: 68°F HEATING
78°F COOLING

VENTILATION: 2 AC/HR MINIMUM

PUMP ROOM & MAGNET STAGING & STORAGE AREAS

TEMPERATURE: 68°F HEATING
NO COOLING CONTROL

VENTILATION: 2 AC/HR MINIMUM

FIRE PROTECTION

SUPPRESSION: AUTOMATIC WET TYPE SPRINKLER SYSTEM DESIGNED FOR ORDINARY HAZARD GROUP-1 WITH SIAMESE CONNECTION.

DETECTION: MANUAL FIRE ALARM PULL STATIONS AT EXITS PLUS IONIZATION TYPE SMOKE DETECTORS.

SERVICE BUILDINGS MI-10, MI-20, MI-30, MI-40, AND MI-50

HVAC SYSTEMS

CONTROL ROOM & KICKER ROOM

TEMPERATURE: 68°F HEATING
78°F COOLING

VENTILATION: 2 AC/HR MINIMUM

POWER SUPPLY ROOM & PUMP ROOM

TEMPERATURE: 68°F HEATING
NO COOLING CONTROL

VENTILATION: 2 AC/HR MINIMUM

FIRE PROTECTION

SUPPRESSION: AUTOMATIC WET TYPE SPRINKLER SYSTEM DESIGNED FOR ORDINARY HAZARD GROUP-1 WITH SIAMESE CONNECTION.

DETECTION: MANUAL FIRE ALARM PULL STATIONS AT EXITS PLUS IONIZATION TYPE SMOKE DETECTORS.

F-0/MI-60 SERVICE BUILDING

HVAC SYSTEMS

TEMPERATURE: 68°F HEATING
78°F COOLING

VENTILATION: 2 AC/HR MINIMUM

FIRE PROTECTION

SUPPRESSION: AUTOMATIC WET TYPE SPRINKLER SYSTEM DESIGNED FOR ORDINARY HAZARD GROUP-2 IN COMPRESSOR AREAS AND GROUP-1 IN ALL OTHER AREAS WITH SIAMESE CONNECTION.

DETECTION: MANUAL FIRE ALARM PULL STATIONS AT EXITS PLUS IONIZATION TYPE SMOKE DETECTORS IN ELECTRONIC AREAS, COMPRESSOR ROOMS, CONTROL ROOMS AND POWER SUPPLY ROOMS.

KICKER BUILDINGS MI-52 AND MI-62

HVAC SYSTEMS

KICKER ROOM

TEMPERATURE: 68°F HEATING
78°F COOLING

VENTILATION: 2 AC/HR MINIMUM

POWER SUPPLY ROOM

TEMPERATURE: 68°F HEATING
NO COOLING CONTROL

VENTILATION: 2 AC/HR MINIMUM

FIRE PROTECTION

SUPPRESSION: AUTOMATIC WET TYPE SPRINKLER SYSTEM DESIGNED FOR ORDINARY HAZARD GROUP-1 WITH SIAMESE CONNECTION.

DETECTION: MANUAL FIRE ALARM PULL STATIONS AT EXITS PLUS IONIZATION TYPE SMOKE DETECTORS.

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	S. KRSTULOVICH/M. OLSON	
DRAWN	E. HUEDEM	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1" = 200'-0" (200 0 200 400 FEET)
1/8" = 1'-0" (8 0 8 16 FEET)

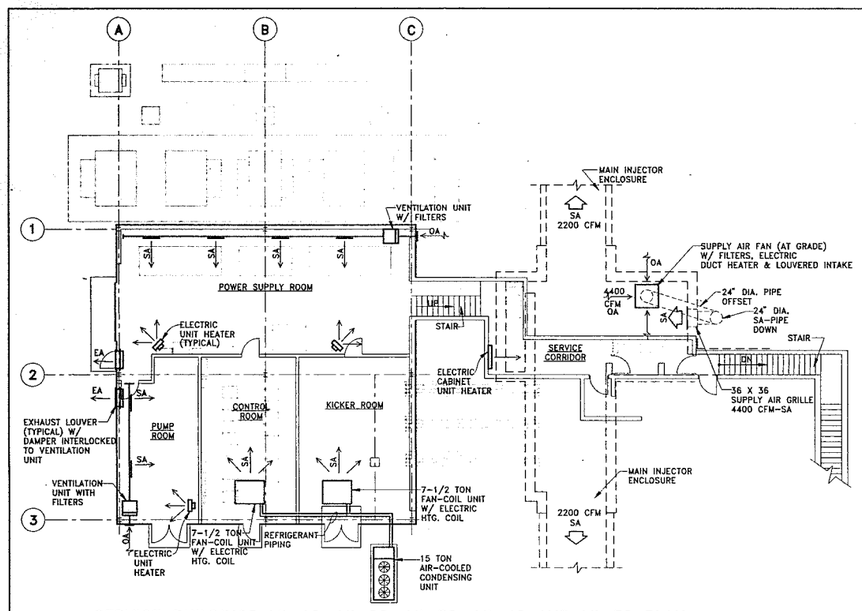
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
HVAC & FIRE PROTECTION CRITERIA

DRAWING NO. 6-6-1 CDR-36 REV.

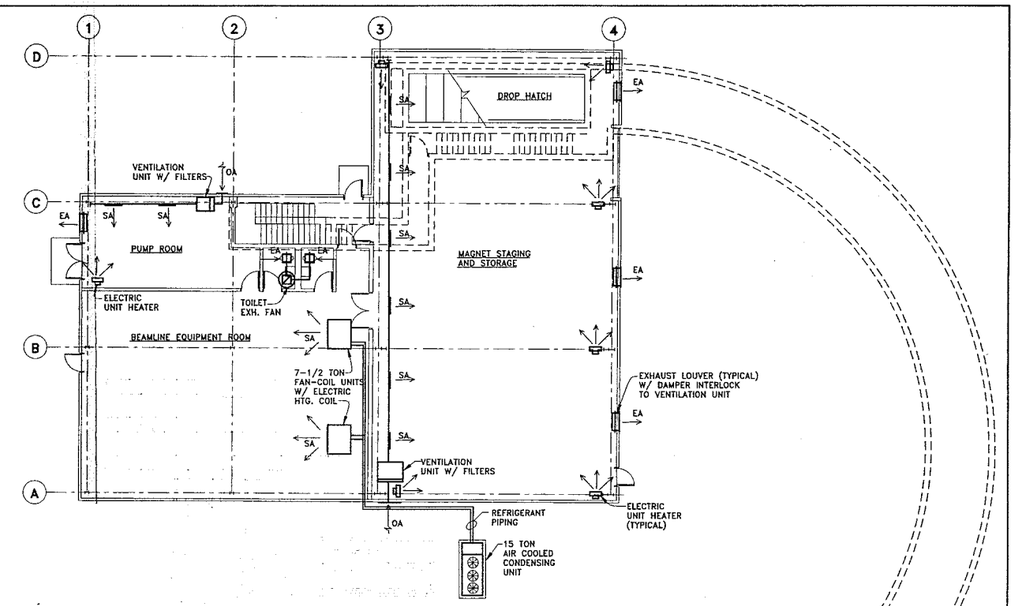
OCT. 1991

04:16:13p.m. 28OCT91



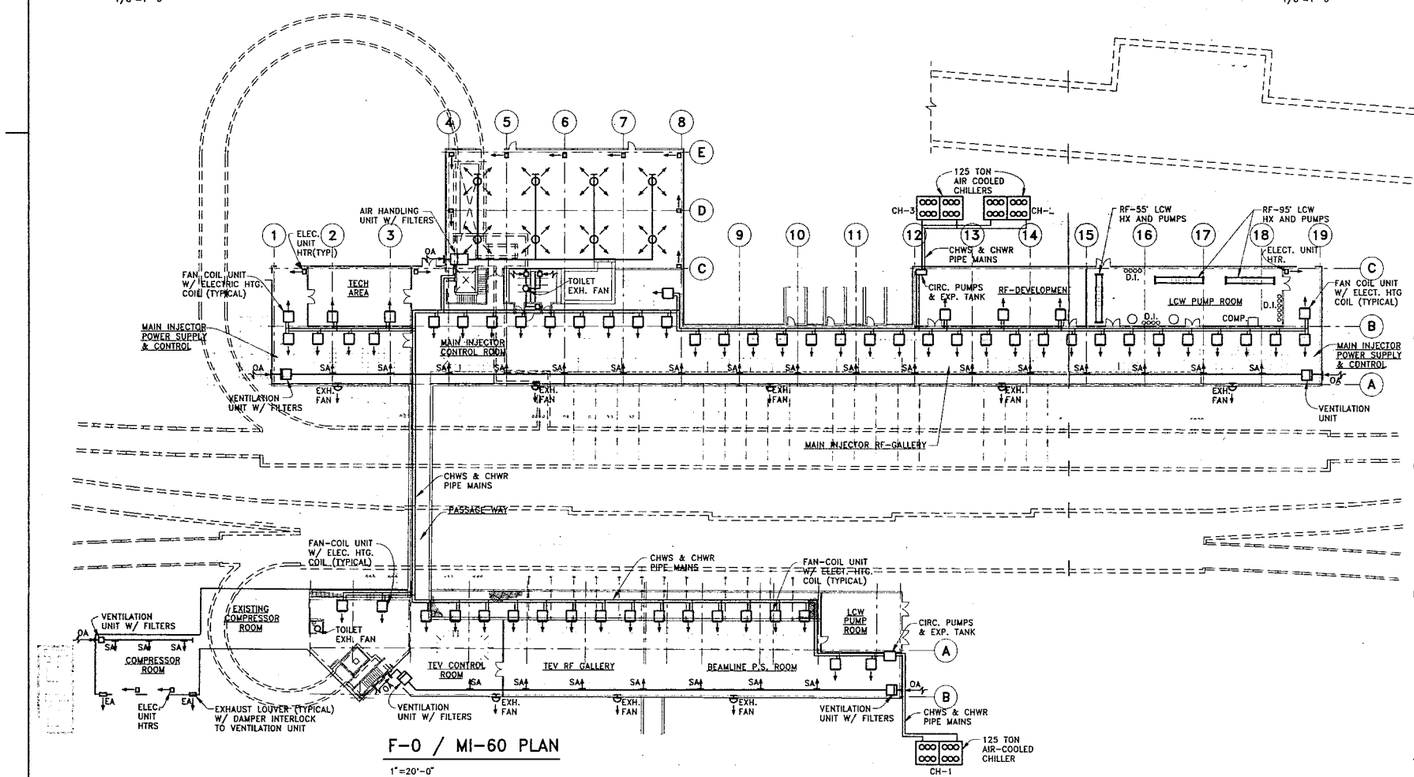
SERVICE BUILDINGS MI-10, MI-20, MI-30, MI-40 AND MI-50 PLAN

1/8"=1'-0"



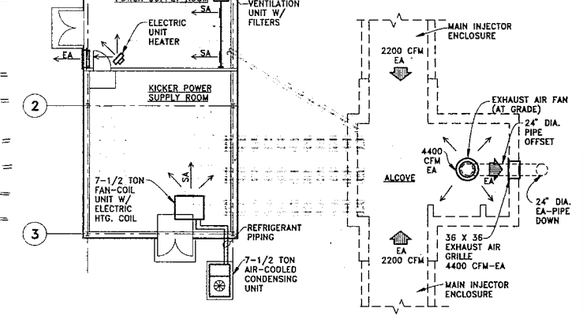
NORTH HATCH BUILDING

1/8"=1'-0"



F-0 / MI-60 PLAN

1"=20'-0"



SERVICE BUILDINGS MI-52 AND MI-62 PLAN

1/8"=1'-0"

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	S. KRSTULOVICH/M. OLSON	
DRAWN	E. HUEDEM	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:
1/8"=1'-0" 8 0 8 16 SCALE FEET
1" = 20'-0" 20 0 20 40 SCALE FEET

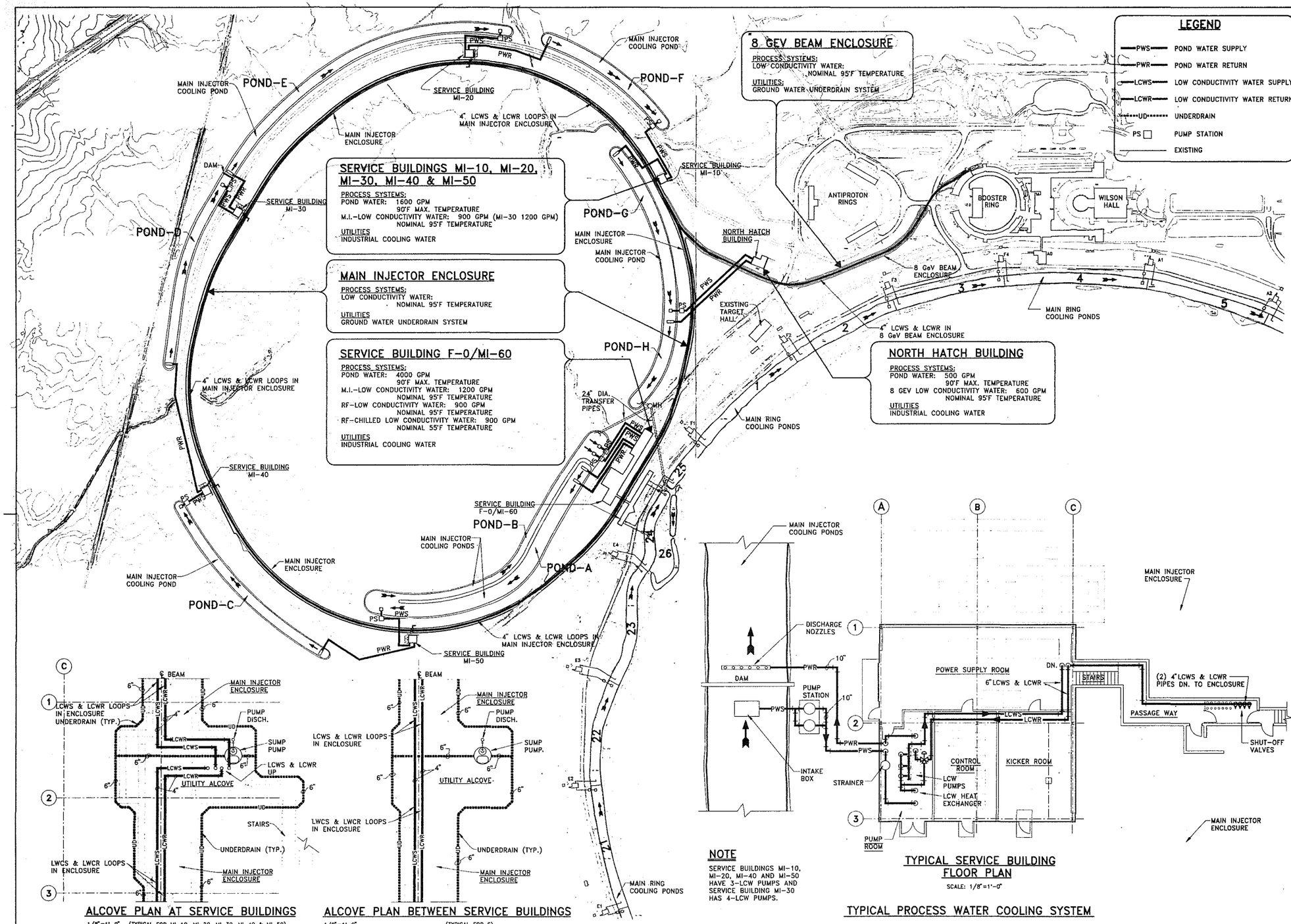
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
HVAC PLANS

DRAWING NO. 6-6-1 CDR-37 REV.

OCT. 1991

04:35:21p.m. 28OCT91



ALCOVE PLAN AT SERVICE BUILDINGS

1/8"=1'-0" (TYPICAL FOR MI-10, MI-20, MI-30, MI-40 & MI-50)

ALCOVE PLAN BETWEEN SERVICE BUILDINGS

1/8"=1'-0" (TYPICAL FOR 6)

NOTE

SERVICE BUILDINGS MI-10, MI-20, MI-40 AND MI-50 HAVE 3-LCW PUMPS AND SERVICE BUILDING MI-30 HAS 4-LCW PUMPS.

TYPICAL SERVICE BUILDING FLOOR PLAN

SCALE: 1/8"=1'-0"

TYPICAL PROCESS WATER COOLING SYSTEM

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	S. KRSTULOVICH/M. OLSON	
DRAWN	E. HUEDEM	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1" = 200'-0" 200 0 200 400 SCALE FEET
1/8"=1'-0" 8 0 8 16 SCALE FEET

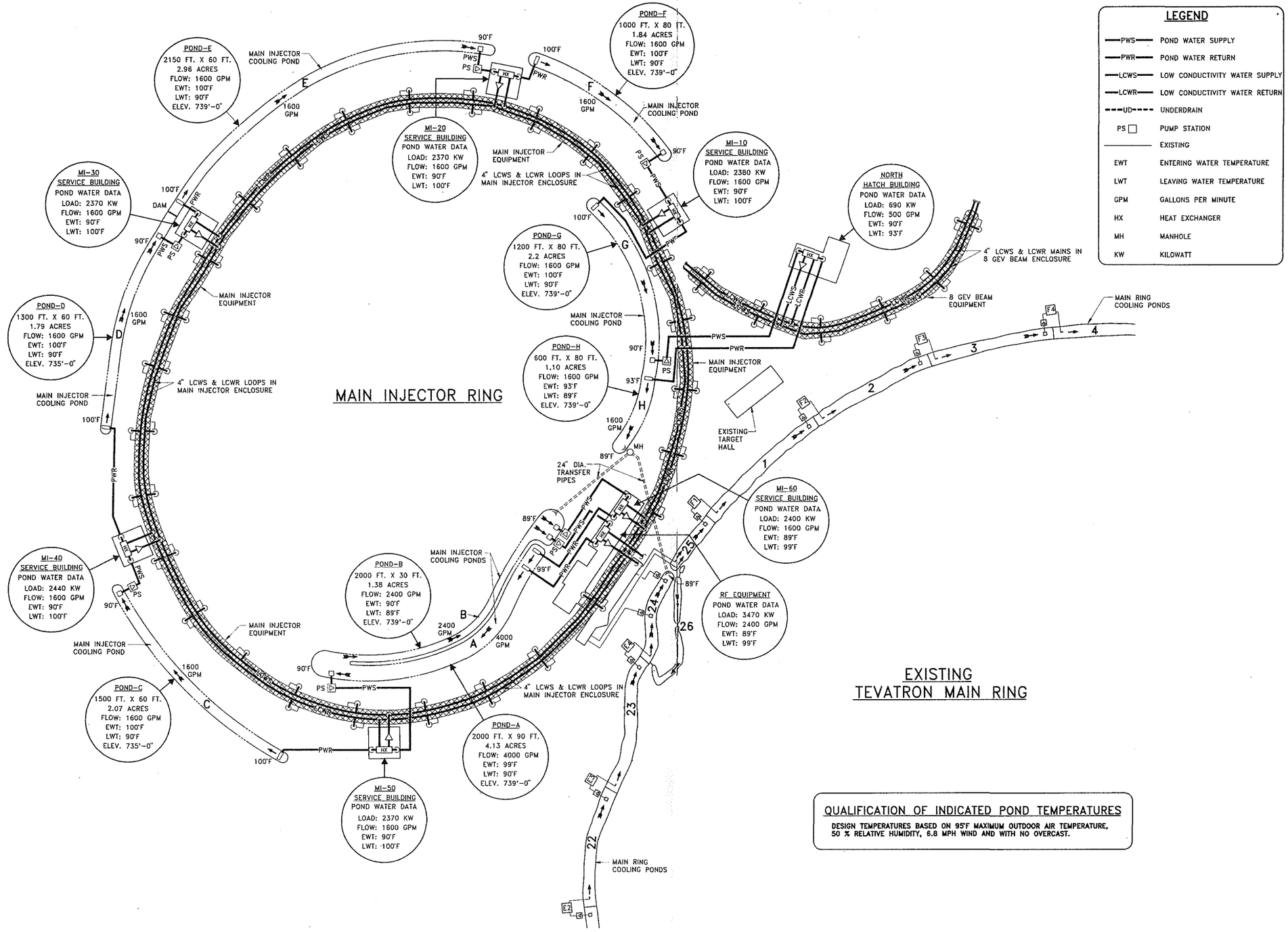
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
PROCESS SYSTEM-CRITERIA

DRAWING NO. 6-6-1 CDR-38 REV.

OCT. 1991

05:35:54p.m. 28OCT91



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	S. KRSTULOVICH/M. OLSON	
DRAWN	E. HUEDEM	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:

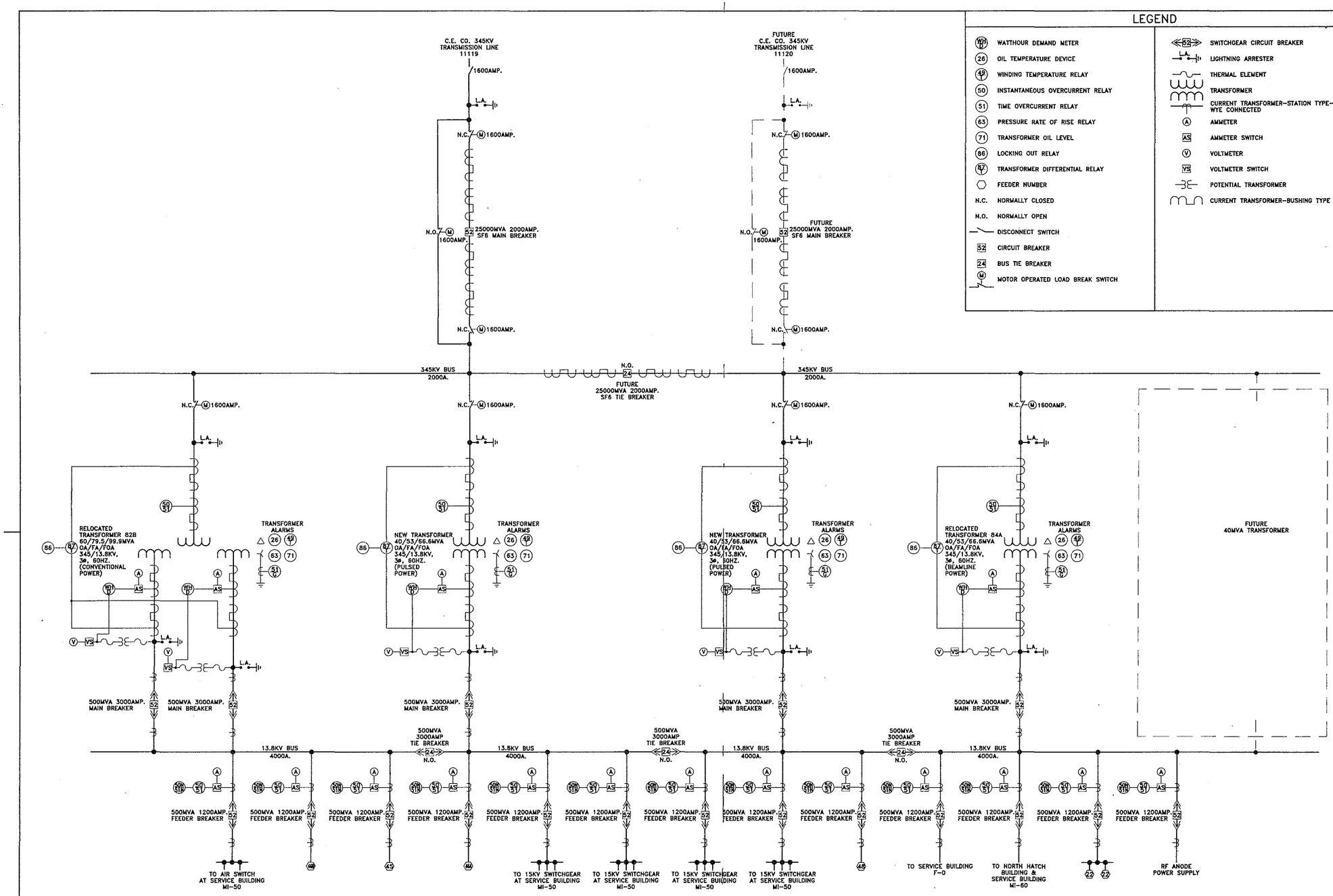
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
PROCESS SYSTEMS – FLOW DIAGRAM

DRAWING NO. 6-6-1 CDR-39 REV.

OCT. 1991

08:25:54p.m. 28OCT91



KAUTZ ROAD SUBSTATION
345-13.8KV SINGLE LINE DIAGRAM

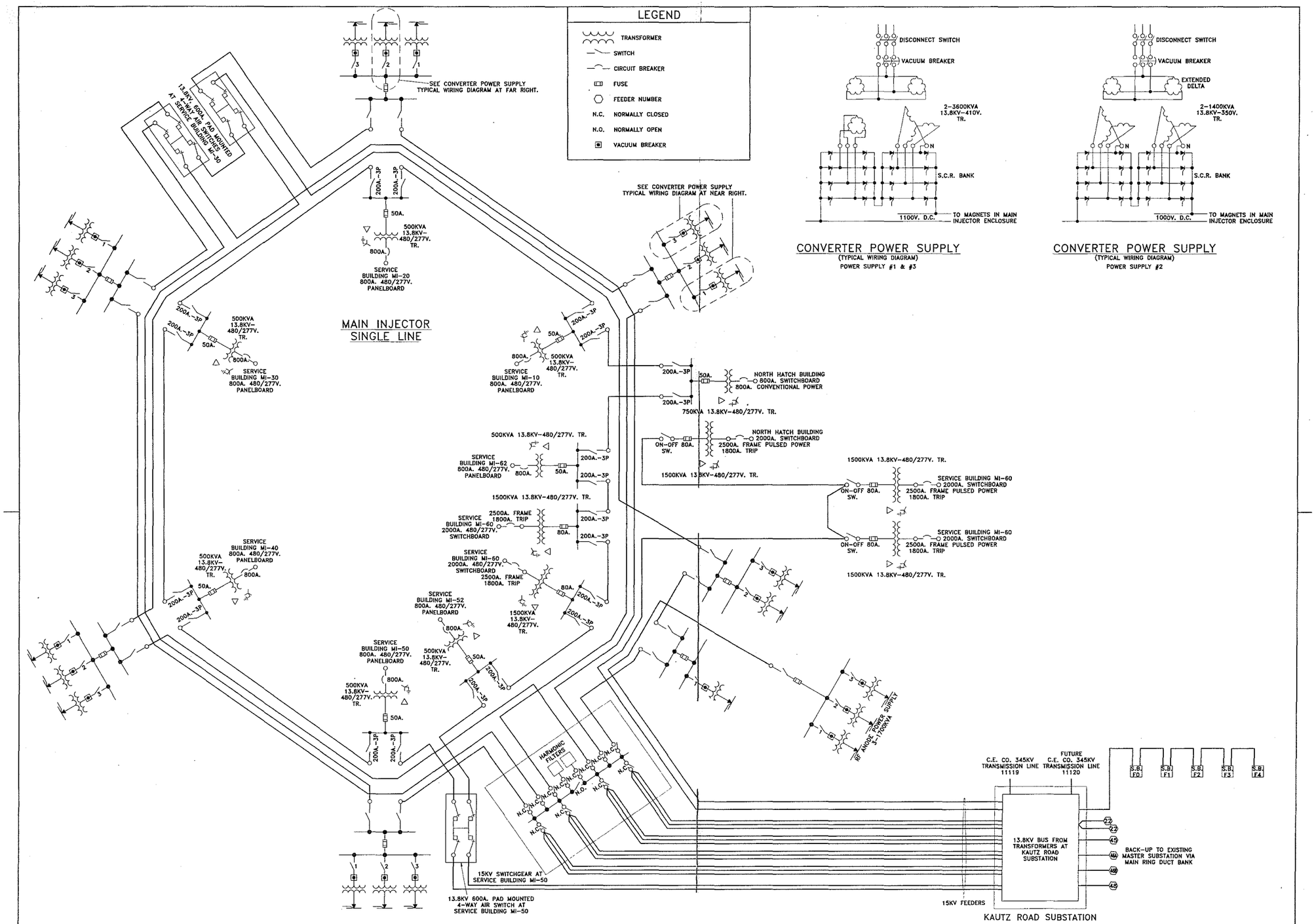
REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	J.RYK/E.VALDES	
DRAWN	A.R.FLOWERS	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
FERMILAB MAIN INJECTOR
345-13.8KV SINGLE LINE DIAGRAM
DRAWING NO. 6-6-1 CDR-40 REV.
OCT. 1991

OCT. 1991



REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	J.RYK/E.VALDES	
DRAWN	A.R.FLOWERS	
CHECKED		
APPROVED		
SUBMITTED		

SCALE:

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
SINGLE LINE POWER DISTRIBUTION

DRAWING NO. 6-6-1 CDR-41 REV.

OCT. 1991

OCT. 1991

DUCT PLAN SYMBOLS

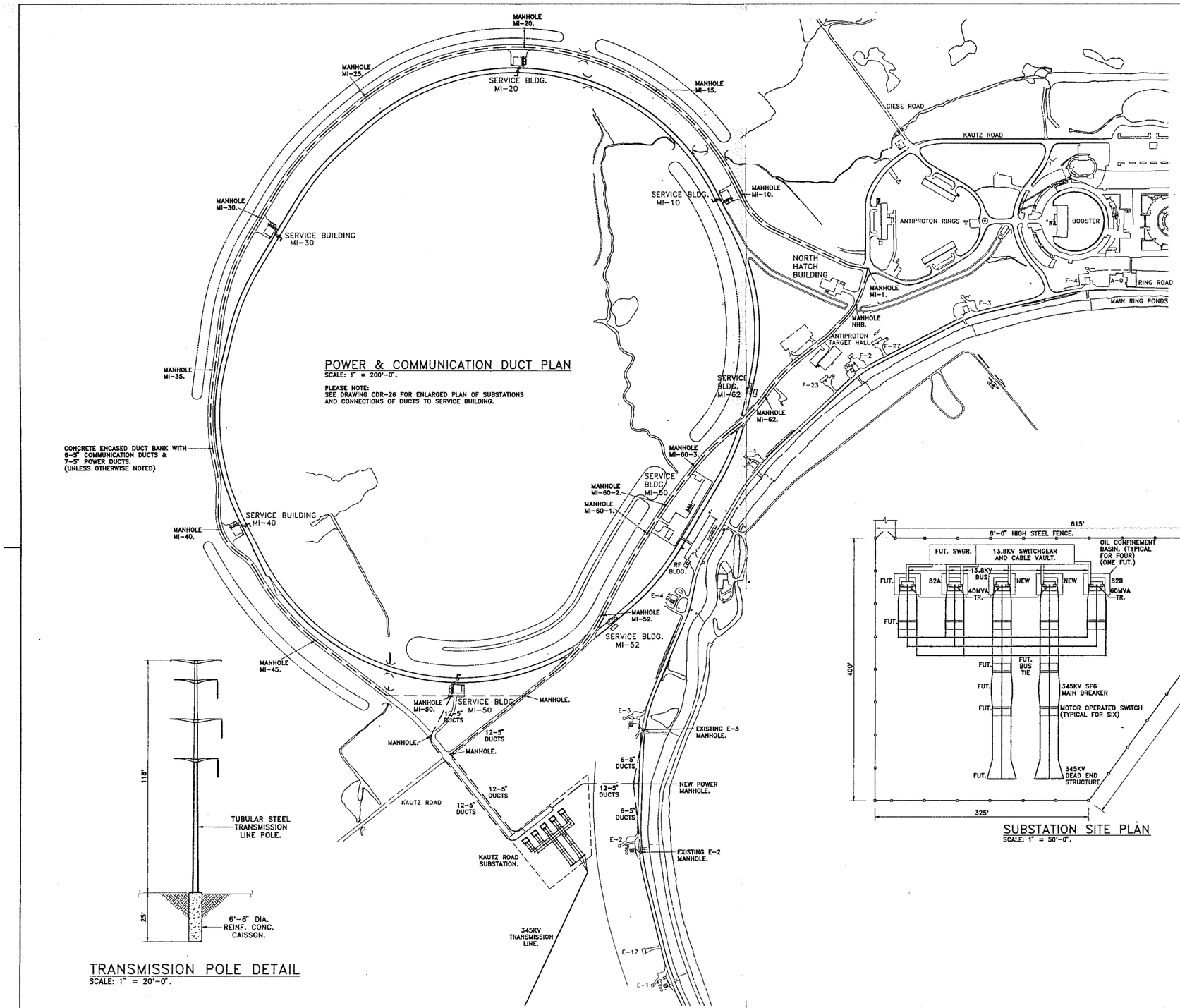
POWER & COMMUNICATION DUCTS

COMMUNICATION DUCT

POWER & COMMUNICATION DUCT PLAN

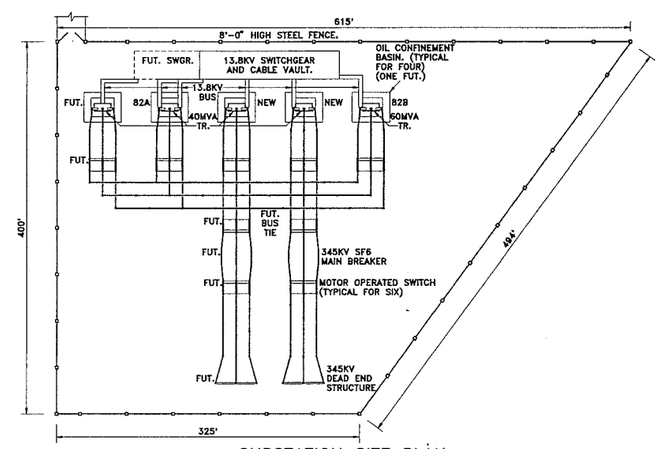
SCALE: 1" = 200'-0".

PLEASE NOTE:
SEE DRAWING CDR-26 FOR ENLARGED PLAN OF SUBSTATIONS AND CONNECTIONS OF DUCTS TO SERVICE BUILDING.



TRANSMISSION POLE DETAIL

SCALE: 1" = 20'-0".



SUBSTATION SITE PLAN

SCALE: 1" = 50'-0".

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	E.VALDES	
DRAWN	A.R.FLOWERS	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE:
1" = 200'-0" SCALE 200 0 200 400 FEET
1" = 50'-0" SCALE 50 0 50 100 FEET
1" = 20'-0" SCALE 20 0 20 40 FEET

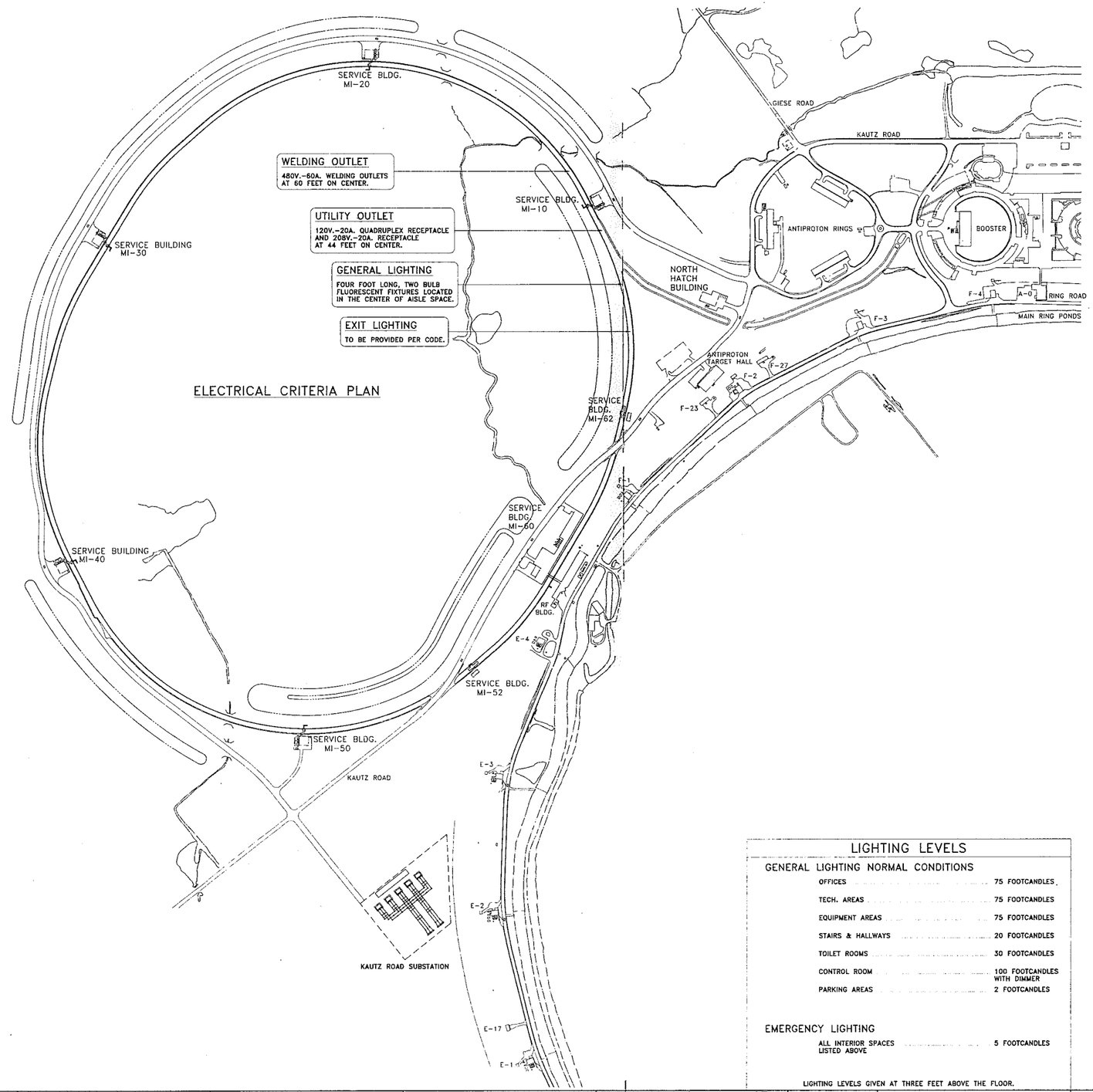
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
POWER & COMMUNICATION DUCT PLAN

DRAWING NO. 6-6-1 CDR-42 REV.

OCT. 1991

OCT. 1991



LIGHTING LEVELS

GENERAL LIGHTING NORMAL CONDITIONS

OFFICES	75 FOOTCANDLES
TECH. AREAS	75 FOOTCANDLES
EQUIPMENT AREAS	75 FOOTCANDLES
STAIRS & HALLWAYS	20 FOOTCANDLES
TOILET ROOMS	30 FOOTCANDLES
CONTROL ROOM	100 FOOTCANDLES WITH DIMMER
PARKING AREAS	2 FOOTCANDLES

EMERGENCY LIGHTING

ALL INTERIOR SPACES LISTED ABOVE	5 FOOTCANDLES

LIGHTING LEVELS GIVEN AT THREE FEET ABOVE THE FLOOR.

REV.	DATE	DESCRIPTIONS
		REVISIONS

	NAME	DATE
DESIGNED	E.VALDES	
DRAWN	A.R.FLOWERS	
CHECKED		
APPROVED		
SUBMITTED		

PROJECT NORTH

SCALE: 1" = 200'-0" (200 0 200 400 SCALE FEET)

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FERMILAB MAIN INJECTOR
ELECTRICAL CRITERIA

DRAWING NO. 6-6-1 CDR-43 REV.

OCT. 1991

OCT. 1991

APPENDIX F

SUPPLEMENTARY PROJECT DATA FOR STRATEGIC FACILITIES

(NOT INCLUDED)