1.0.1.2
Recycler Kicker Eng. & Design
2.0.1.2
Recycler Kicker Construction

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CD-2/3a Director's Review of NOνA
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Overview

- 5 New Kicker Systems for Recycler Beam Transport
- Specifications Have Been Revised
- Cost Estimate based on recent experience
  - NuMI Kicker System
  - MI Injection Kicker Upgrades
- Schedule driven by new magnet prototype, ceramic chamber delivery and chamber vacuum flanging
  - Order for ceramic chamber has been placed
  - Order for flanging of test chamber placed and work in progress
- All requirements are achievable
  - Kicker systems are on the critical path for this sub-project
  - Mechanical engineering & drafting labor is tight
  - Prototyping has started

WBS Description with Costs

(costs are fully burdened FY07$, contingency % separate)

1.0.1.2 Recycler Kicker System Planning Engineering and Design ($3.8M, 29%)

- 1.0.1.2.1 Prototype Injection Kicker Magnet ($1.2M, 32%)
  - Prove performance and order all ceramic chambers
- 1.0.1.2.2 Prototype Injection Kicker Pulser ($920K, 25%)
- 1.0.1.2.3 Prototype Bumper Pulser ($276K, 24%)
- 1.0.1.2.4 Prototype Extraction Line Kicker Magnets ($1.3M, 30%)
- 1.0.1.2.5 Extraction Line Kicker Power Supply ($33K, 30%)
- 1.0.1.2.6 Reviews ($13K, 20%)

2.0.1.2 Recycler Kicker System Construction ($10.3M, 33%)

- 2.0.1.2.1 & 2.0.1.2.2 Production of Injection Kicker Magnets and Pulsers ($5.8M, 35%)
  - Includes gap clearing kickers
- 2.0.1.2.3 & 2.0.1.2.4 Extraction Kicker Magnets and Pulsers ($3.6M, 29%)
  - Separate tasks for MI kicker magnet and RR kicker magnet
- 2.0.1.2.5 & 2.0.1.2.6 Full Turn Abort Kicker Magnets and Pulsers ($849k, 30%)
  - Same design as RR Extraction kicker system
- 2.0.1.2.7 Oversight of TD Kicker Magnet Construction ($53K, 10%)

RR Injection and Gap Clearing Performance Specifications

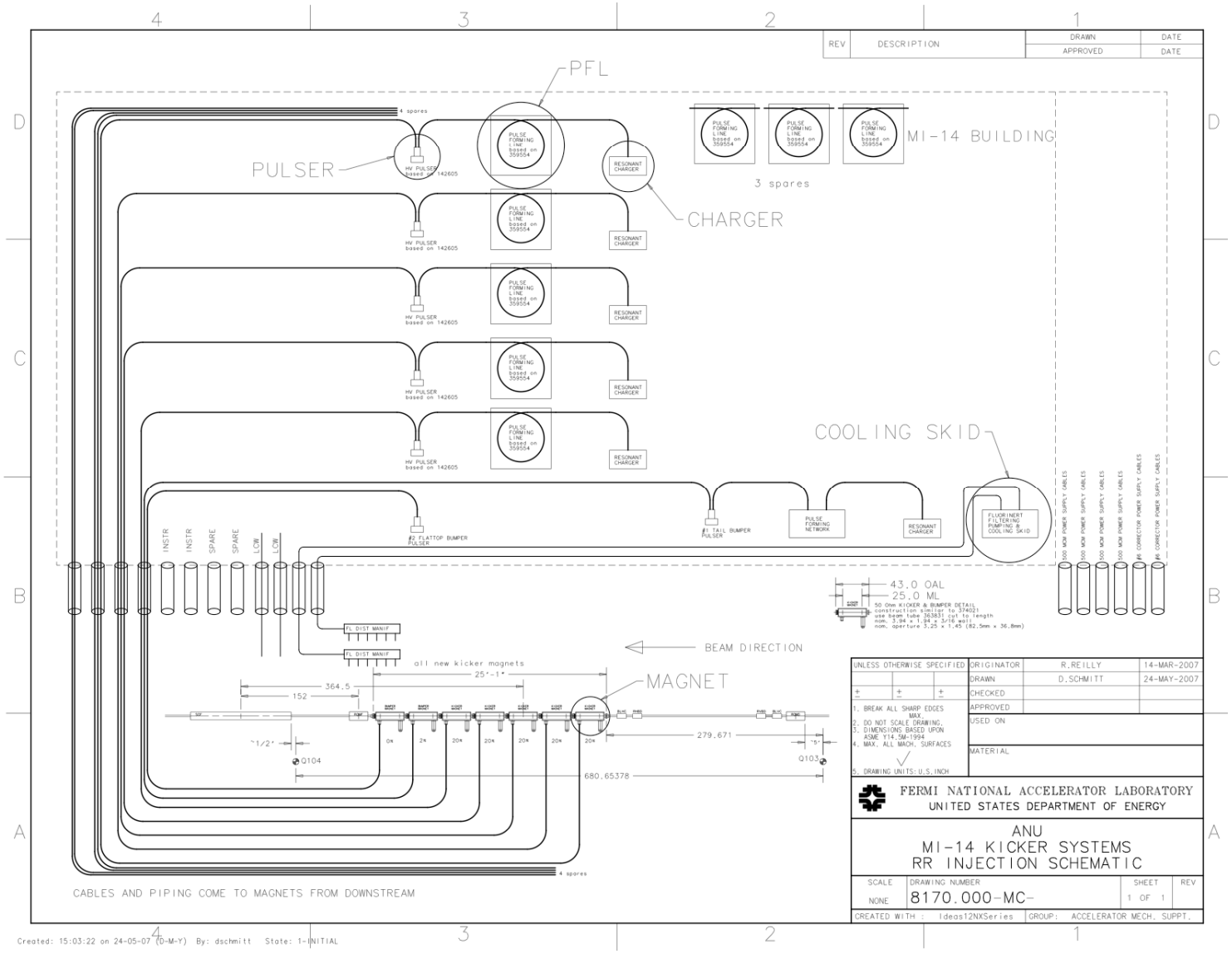
- Specification changes since last review
  - Longer field rise and fall time (57 ns was 38 ns) *
  - Flattop 1 bunch shorter (1534 ns)
  - Increase total field strength (360 G•m was 300 G•m)
    - Add 10% more for operational tuning range -> 400 G•m
- Design Changes since last review
  - Fewer pulser / magnet systems
    - 5 main + 2 bumper was 7 main + 2 bumper
  - Magnets are longer

RR Injection and Gap Clearing Performance Specifications

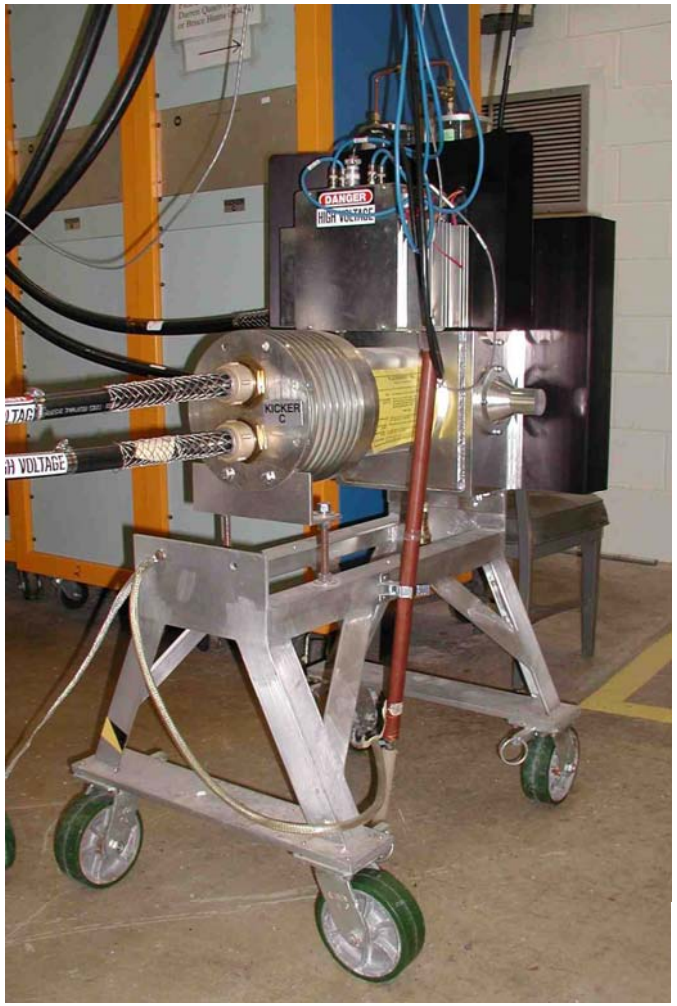
- Specifications
  - Field rise time / fall time 57 ns
  - Flattop length 1534 ns
  - Injection Repeatability ± 1/2% , Stability ±1%
  - Gap Clearing Repeatability ± 2% , Stability ±4%
  - Strength 360 G•m
  - 12 pulses @ 15 Hz, 9 Hz average
  - Vacuum < 10^{-8} Torr

- Bumper system still required to meet fall time
  - One supply / magnet for coarse tuning (fall time)
  - One supply / magnet for fine tuning (flat top and post pulse)

RR Injection / MI-14 Layout



Pulser / Pulse Forming Line



Cooling Skid / Magnet Load

Magnet

RR Injection and Gap Clearing Cost Details (costs are fully burdened FY07$, contingency % separate)

- RR Injection Kicker System Development
  - Magnet Development Total Cost $1.2M (32% contingency) (1.0.1.2.1)
  - Pulser Development Total Cost $920K (25% contingency) (1.0.1.2.2)
  - Bumper Power Supply Development Total Cost $276k (24% contingency) (1.0.1.2.3)

- RR Injection Kicker / Gap Clearing Kicker System Construction
  - Cost is split 50/50 between two identical systems
  - Magnet Construction Total Cost $1.9M (38% contingency) (2.0.1.2.1)
  - Pulser Construction Total Cost $3.9M (34% contingency) (2.0.1.2.2)

RR Injection and Gap Clearing Design Issues, Progress & Plans

Design Issues:

- Need fast pulser and short magnets to meet rise time
- Need bumper system to meet fall time and ± 1% flatness
- Need load temperature control to maintain ± 1/2% repeatability
  - Also needed to remove heat from load

Progress up to now:

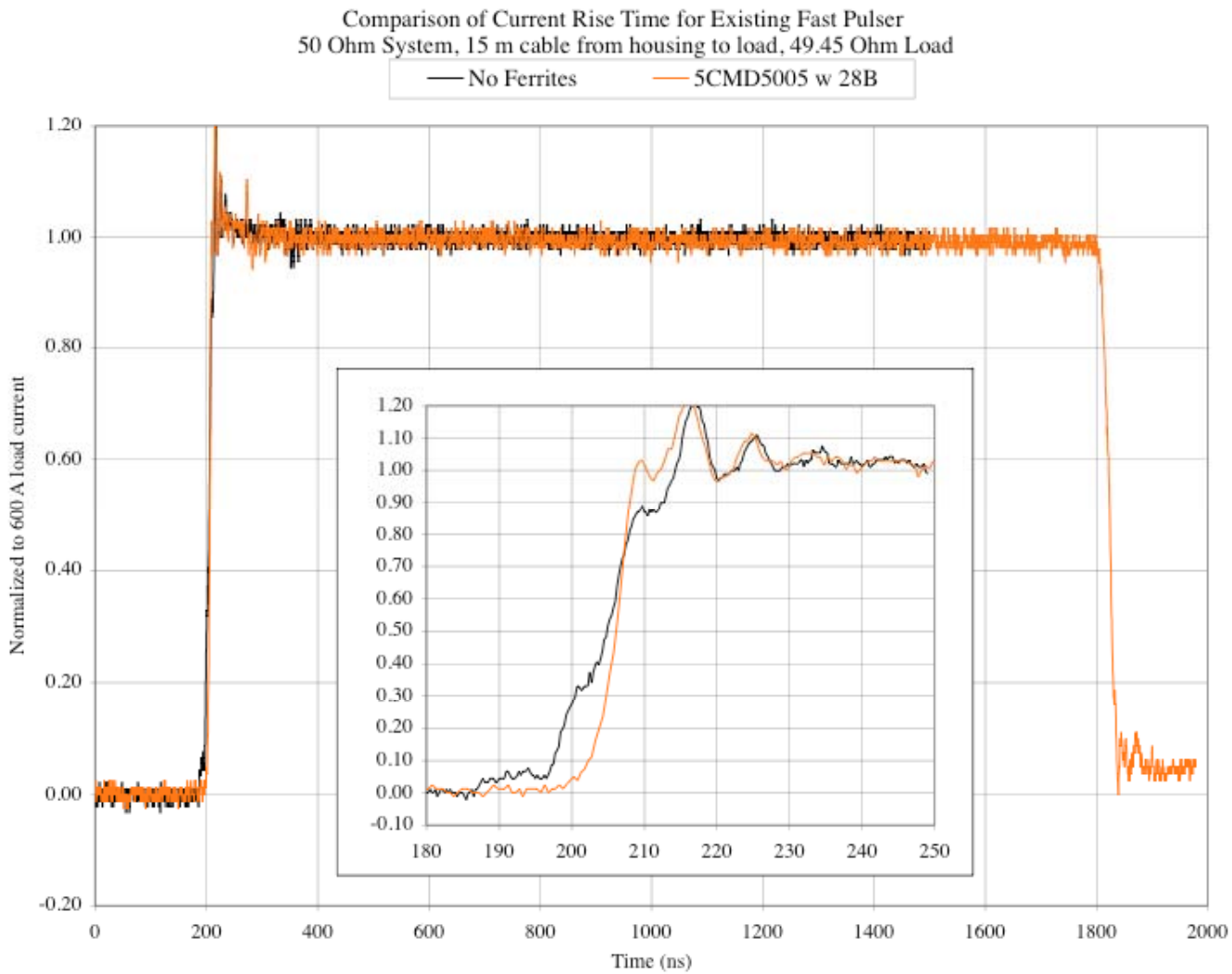
- Existing Tevatron injection pulser tested with 50 Ohm load
  - Ferrite sharpening results are encouraging for reducing rise time

Next 6 months:

- Complete design of prototype magnet
  - Order long lead time ferrite for magnet
- Start Testing of prototype pulsers
  - Build control system

RR Injection and Gap Clearing Design Issues, Progress & Plans

RR Injection and Gap Clearing Design Issues, Progress & Plans



RR Extraction and MI Injection Performance Specifications

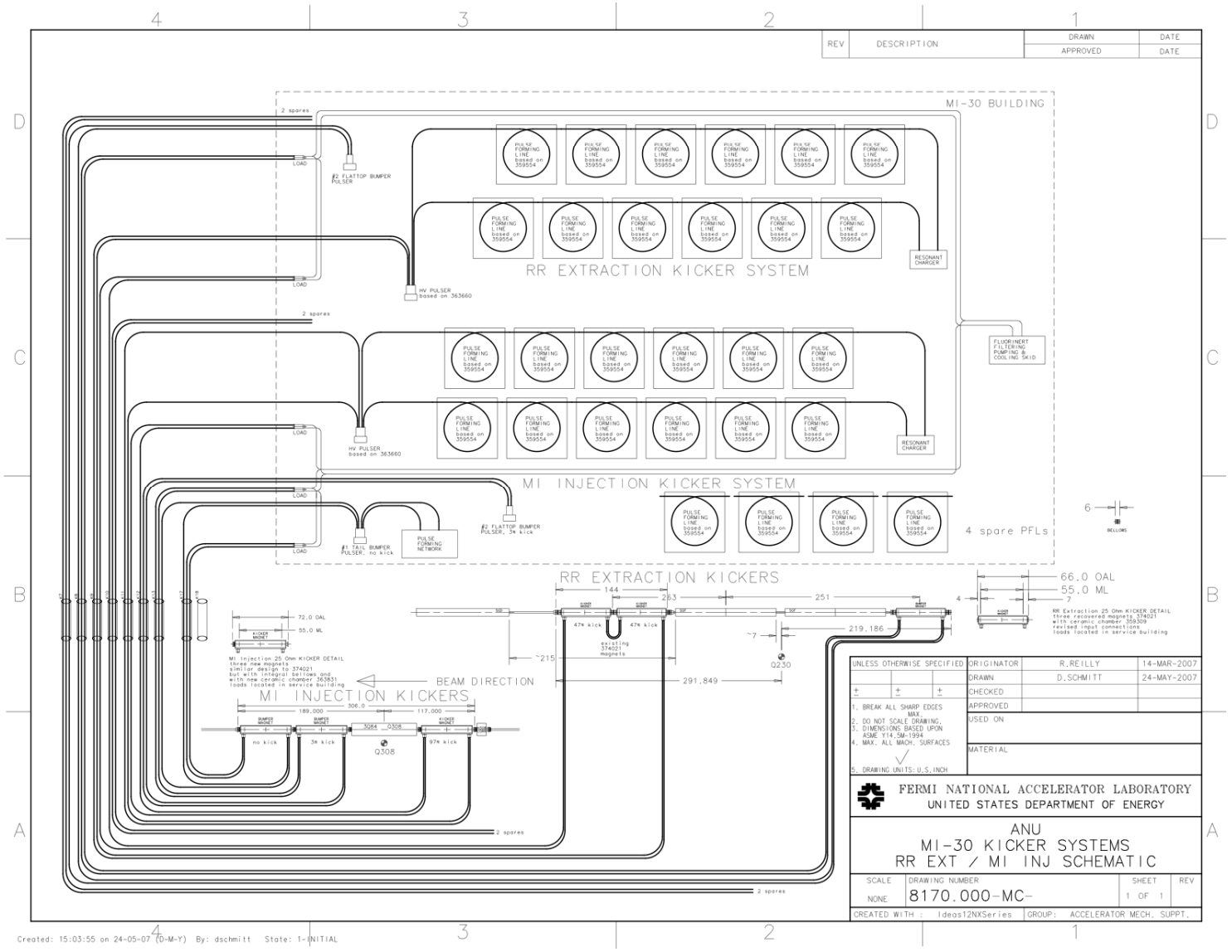
(costs are fully burdened FY07$, contingency % separate)

- Specification changes since last review
  - All magnets have same aperture (MI was larger than RR)
  - Increase strength of RR Extraction (500 G•m was 320 G•m)
  - Decrease strength of MI Injection (370 G•m was 610 G•m)
- Design changes since last review
  - Move magnet terminations to service building
  - Minor update of existing kicker magnet instead of new design
  - RR Extraction now two kicker magnets in series
- Total Construction Cost $3.6M (29% contingency)

RR Extraction and MI Injection Performance Specifications

- Specifications
  - Field rise time 1.65 µs
  - Field fall time (MI Injection only) 1.65 µs
  - Flattop length 9.49 µs
  - Repeatability ± 1/2% , Stability ±1%
  - RR Extraction strength 500 G•m
  - MI Extraction strength 370 G•m
  - Pulse rate 1/1.3 s (0.75 Hz)
  - Vacuum < 10^{-8} Torr

RR Ext / MI Inj / MI-30 Layout



RR Extraction and MI Injection Performance Specifications

- RR Extraction Kicker
  - Refurbish existing magnets
- MI Injection Kicker
  - Tight regulation after fall time requires bumper system
  - One supply / magnet for coarse tuning (fall time)
  - One supply / magnet for fine tuning (flat top and post pulse)

RR Extraction and MI Injection Design Issues, Progress & Plans

Magnet Design Issues:

- Update design to incorporate reliability improvements
  - Need 3 more magnets of same performance as existing
  - Larger aperture of new ceramic chambers needed in 3 magnets

Progress up to now:

- Have parts for putting cable in series for long pulse
  - Initial testing at 50 kV has good performance

Next 6 months:

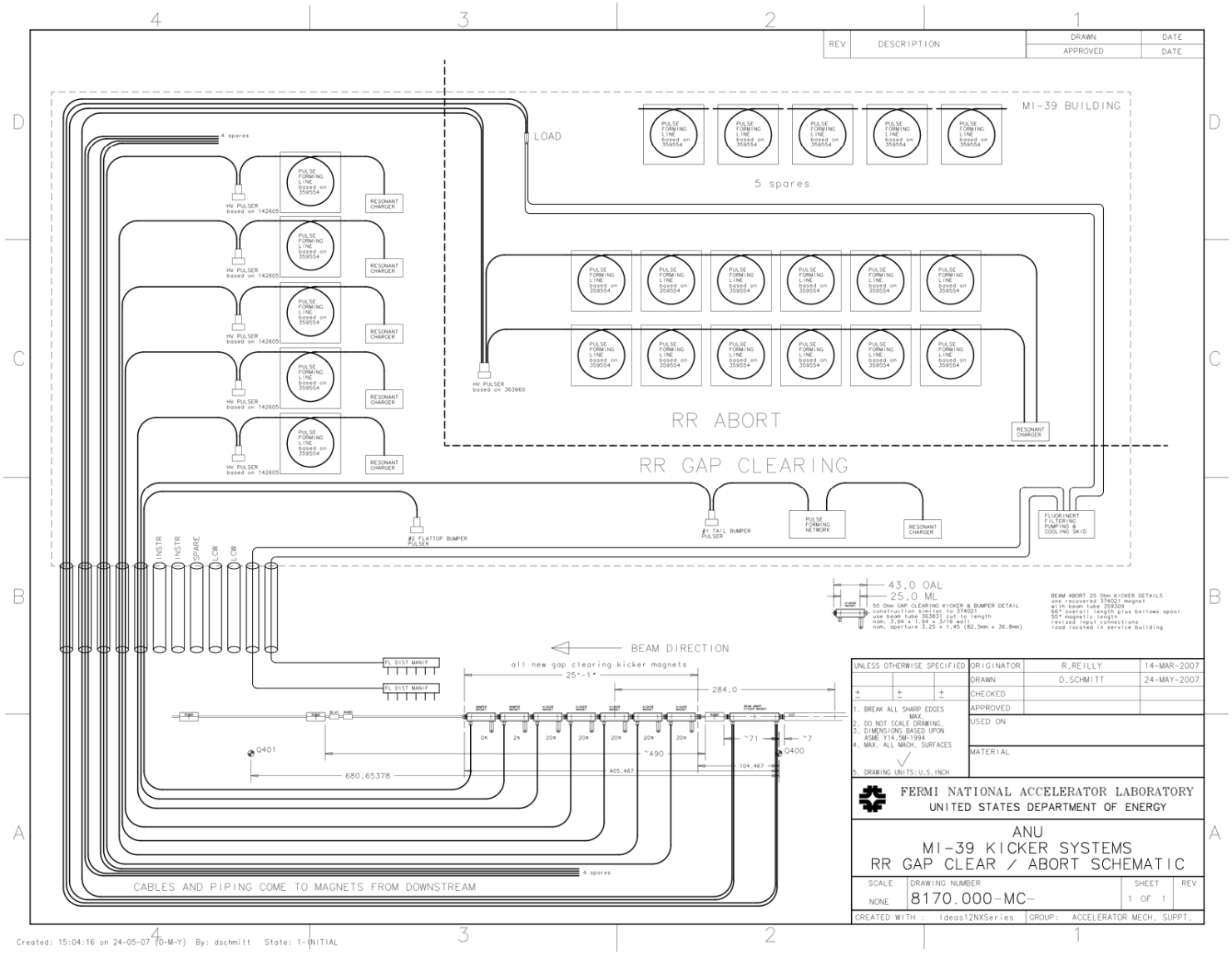
- Begin design updates of magnet
  - Build on design updates made for new RR Injection
- Order two different capacitor values for new magnets
  - Have enough to do any value over range

RR Abort System Performance Specifications

(costs are fully burdened FY07$, contingency % separate)

- Specifications
  - Field rise time 1.65 µs
  - Flattop length 9.49 µs
  - Repeatability ± 2% , Stability ±4%
  - Strength 320 G•m
  - Pulse rate 1/1.3 s (0.75 Hz)
  - Vacuum < 10^{-8} Torr
- $849k Total Cost, 30% Contingency

RR Gap Clearing / Abort / MI-39



RR Abort System
Design Issues, Progress & Plans

Design Issues:

- Use six series pulse forming lines (PFL) to reduce design and construction time

Progress up to now:

- Not part of the critical path

Next 6 months:

- Run standard PFL cable at full voltage with connectors
  - High voltage test needs pulser, pulser controls, load and cooling
  - Run test for extended period above nominal voltage

Value Engineering

- May be able to re-use existing pulse forming cable for RR abort and RR extraction – have costed for new cable
  - Cable currently in service for Tevatron proton injection kicker
- Reuse existing RR magnets with minor modifications for abort and extraction
  - No fall time requirement for these
- Larger aperture magnets for MI injection
  - Updated design has slightly larger ceramic – good fit to needs
- Build on existing pulser design strengths for RR injection
- Build on existing magnet design strengths for RR and MI injection

Risk Management

Risk Management:

- Main risk is not having enough ceramic beam tubes for these systems. Details/mitigation given in NOvA Risk Form (NOvA-DocDB-1444)
  - Ordering assuming 60% don't meet specs (anything left is spares/inventory)
  - Vendor visits throughout the fabrication process, substantial lead time in orders
  - Investigating backup vendors in the process
- New MI Injection magnets
  - Two capacitors for reduced schedule risk
- RR and MI Injection prototypes are being built to determine performance
- AD lead / TD production
  - TD some recent experience building kickers
  - Long learning curve
  - Early TD involvement in prototype for reduced production risk

Conclusions

(costs are fully burdened FY07$, contingency % separate)

- Cost and Schedule are based on what is achievable
- Design of pulsers and magnets will have prototype to determine performance
- Planning, Engineering & Design Cost $3.8M
  - 29% contingency
- Construction Cost $10.3M
  - 33% contingency
- Schedule
  - Driven by ceramic vacuum chamber and prototyping
  - RR Injection kickers near the critical path
  - Procure ceramic chambers has started to reduce impact of long lead times