MI RF SYSTEM UPGRADE

SECTION 3.1

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MI RF SYSTEM UPGRADE

SCOPE

I. Summary of RF System Parameters – Table I.

II. Modifications Required to Existing 53 MHz System

- **Existing 53 MHz RF Cavities – Modification**
- **RF Amplifiers**
- **Modulators**
- **Anode Supplies**
- **RF Controls**
- **Utilities**

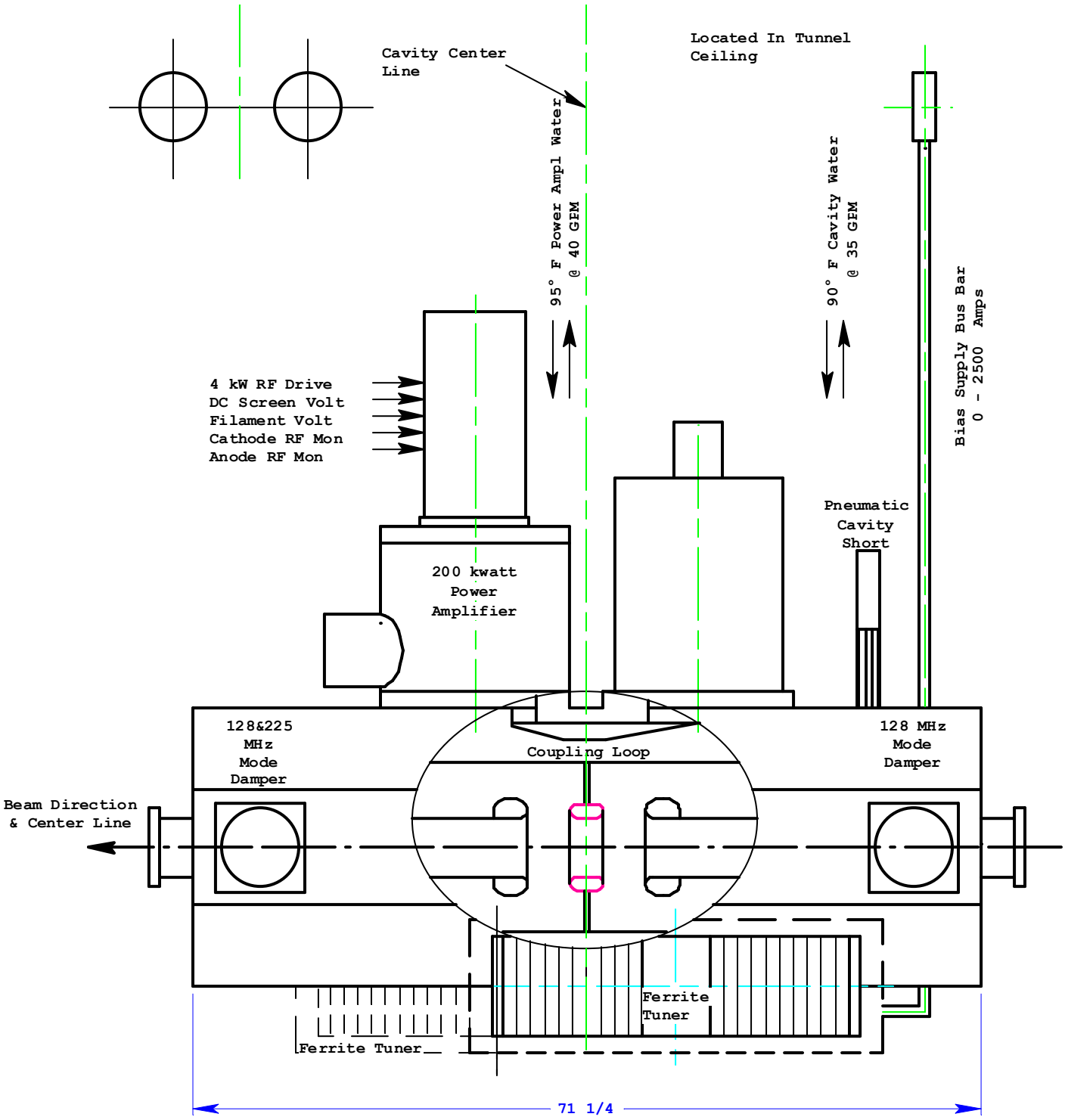
III. New 53 MHz RF Cavity & Power Amplifier

- **Cavity Proposal**
- **Power Amplifier**

IV. R&D

	Present Main Injector	Upgraded Main Injector	Upgraded Main Injector
		Modified Existing Cavity	New Cavity Design
Harmonic number	588	588	588
Number of filled buckets	498	500	500
Frequency:	52.813 – 53.104 MHz	52.813 – 53.104 MHz	52.813 – 53.104 MHz
Acceleration ramp slope:	240 Gev/s	240 Gev/s	240 Gev/s
Beam intensity:	3.0e13 protons	1.5e14 protons	1.5e14 protons
Beam accelerating power:	1.15 Megawatts	5.76 Megawatts	5.76 Megawatts
Number of accelerating cavities:	18	20	14
Cavity R/Q:	105	105	25
Accelerating power per cavity (beam):	64 Kilowatts / Cavity	288 Kilowatts / Cavity	412 Kilowatts / Cavity
Maximum cavity accelerating voltage:	235 Kilovolts / Cavity	235 Kilovolts / Cavity	300 Kilovolts / Cavity
Accelerating voltage required: $V\sin\varphi_s$	2.66 Megavolts	2.66 Megavolts	2.66 Megavolts
Total accelerating voltage available:	4.23 Megavolts	4.70 Megavolts	4.20 Megavolts
Total peak amplifier power required:(beam + cavity)	~130 Kilowatts	~ 800 Kilowatts	~ 800 Kilowatts

RF Parameter Table I



As Viewed From Aisle Side

Present Main Injector Cavity

Figure 1

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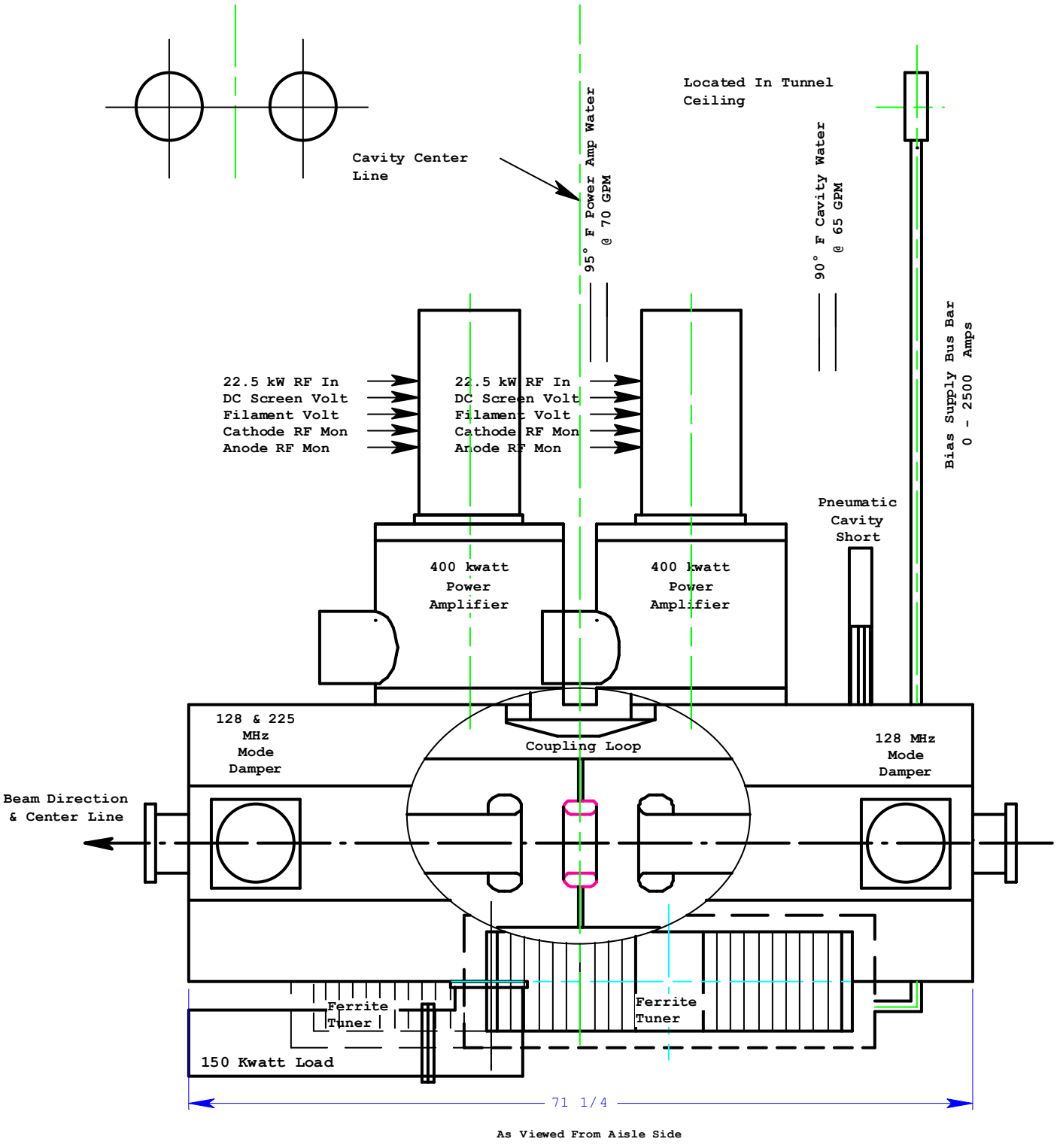

Modified Main Injector Cavity for Two Power Amplifiers

Figure 2

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RADIO FREQUENCY SYSTEMS

II. Modifications Required to Existing 53 MHz System

- **Modify 20 Existing 53 Mhz RF Cavities**

1. **Remove balancing "top hat" capacitor from existing cavities.**
2. **Fabricate 20 coupling loops for Power Amplifiers.**
3. **Install 20 – 150 Kwatt water loads with coupling loops.**
4. **Fabricate new dampers (HOM) for each cavity.**

- **RF Amplifiers**

1. **Fabricate 20 additional 400 Kwatt Power Amplifiers.**
2. **Fabricate 20 – 50 Kwatt tube driver amplifiers with power supplies.**
   a. **Desirable to locate this driver in tunnel for max rf feedback gain.**
   b. **Power supplies located upstairs in equipment gallery.**
   c. **Fabricate control unit.**
3. **Procure 20 –100 watt solid state amplifiers (pre-driver).**

- **Modulators**

1. **Fabricate 20 new modulator that can handle output of 21 Kvolts @ 40 Amps.**
2. **Equipment gallery can tolerate a slightly larger modulator footprint.**
3. **New higher power series tube (for handling two PA's).**
4. **New floating deck for higher power series tube.**
5. **New Grid, Screen, & Filament power supplies for operating two Power Amplifier combination.**
6. **Reuse existing MI modulators for Booster upgrade.**

- **Anode Supplies**

1. **Modify existing three anode power supplies.**
a. **Higher power main rectifier transformer**
b. **Higher power rectifier stack**
c. **Capacitor bank**
d. **Interphase reactor**
e. **Water resistor**
f. **Possibly new fast 13.8 Kvolt step start contactor.**

2. **Build additional three power supplies**
a. **Supplies are built as separate rooms off existing west side of MI-60 building.**
b. **Physical space to locate these supplies would have to be worked out.**
c. **Supplies would be vary similar to existing units.**

- **RF Controls**

1. **Much of the rf controls would remain unchanged.**
2. **Direct rf feedback will be employed along with rf feed-forward compensation.**

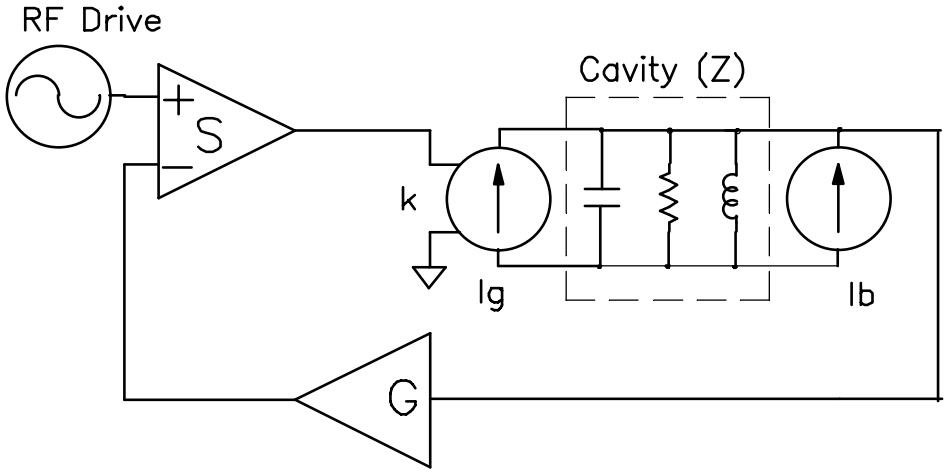

Figure 3: Direct RF Feedback Block Diagram. G is the feedback gain, and k is the tube transconductance.

3. **Various control parts would have to be fabricated for the additional two stations.**

- **Utilities**

1. **AC Power**

There is sufficient power available in the equipment gallery for most of required upgrades. 13.8 Kvolt Anode supply feeder may need to be upgraded.

2. **LCW Cooling**
   Some upgrade to the existing closed loop waters systems will be required. Table II shows present requirements along with upgrade requirements.

95 degree LCW		**Present Configuration 18 stations**	**Upgraded RF System 20 stations**
	Ferrite Bias Supply	306 gpm	340 gpm
	Series Tube Modulator	630 gpm	1400 gpm
	Power Amplifier # 1	630 gpm	630 gpm
	Power Amplifier # 2	0	630 gpm
	Driver Amplifier	180 gpm	400 gpm
	Anode Supplies	105 gpm	210 gpm
	2.5 Mhz Coalescing	72 gpm	72 gpm
	Test Station	~200 gpm	~300 gpm
	Total	**2123 gpm**	**3982 gpm**
	Average Heat Load (50% DF)	~3.3 Mwatts	~7.5 Mwatts
90 degree Cavity LCW			
	RF Cavity	630 gpm	1300 gpm
	Test Station	~100 gpm	~200 gpm
	Total	**730 gpm**	**1500 gpm**
	Average Heat Load (50% DF)	~0.5Mwatts	~2.5 Mwatts

Table II. LCW requirements

3. **Cable Trays & Cabling**
   a. **Additional cabling and some cable trays will be required.**
   b. **Support for the two additional stations.**
   c. **Cabling to support two power amplifiers on each cavity.**

III. New RF Cavity & Amplifier System

- **New Cavity**

1. **Advantages**
   a. **Replacements for 30 year old cavities.**
   b. **Low R/Q.**
   c. **Help in solving the longitudinal beam instability.**
   d. **Help in transient beam loading.**
   e. **Fewer cavities running at higher voltage.**

2. **Sketch of cavity shown in Figure 4.**

3. **Tuner would be perpendicularly biased.**
   a. **Yttrium Garnets.**
   b. **Bias above resonance for Q > 20,000.**
   c. **Use existing bias supply for single layer solenoid.**
   d. **μ from 2.5 to 1.2.**

- ## New Power Amplifier

1. **Based on Eimac 8973 Tetrode.**
2. **Cathode driven with grid grounded.**
3. **Capable of delivering greater than 1 Mwatt of rf power to load.**

- ## Support Equipment for Above System.

Much of the same equipment, 50 Kwatt rf driver, Modulator, & Anode supply capacity would be essentially the same as used in the modified two amplifier approach.

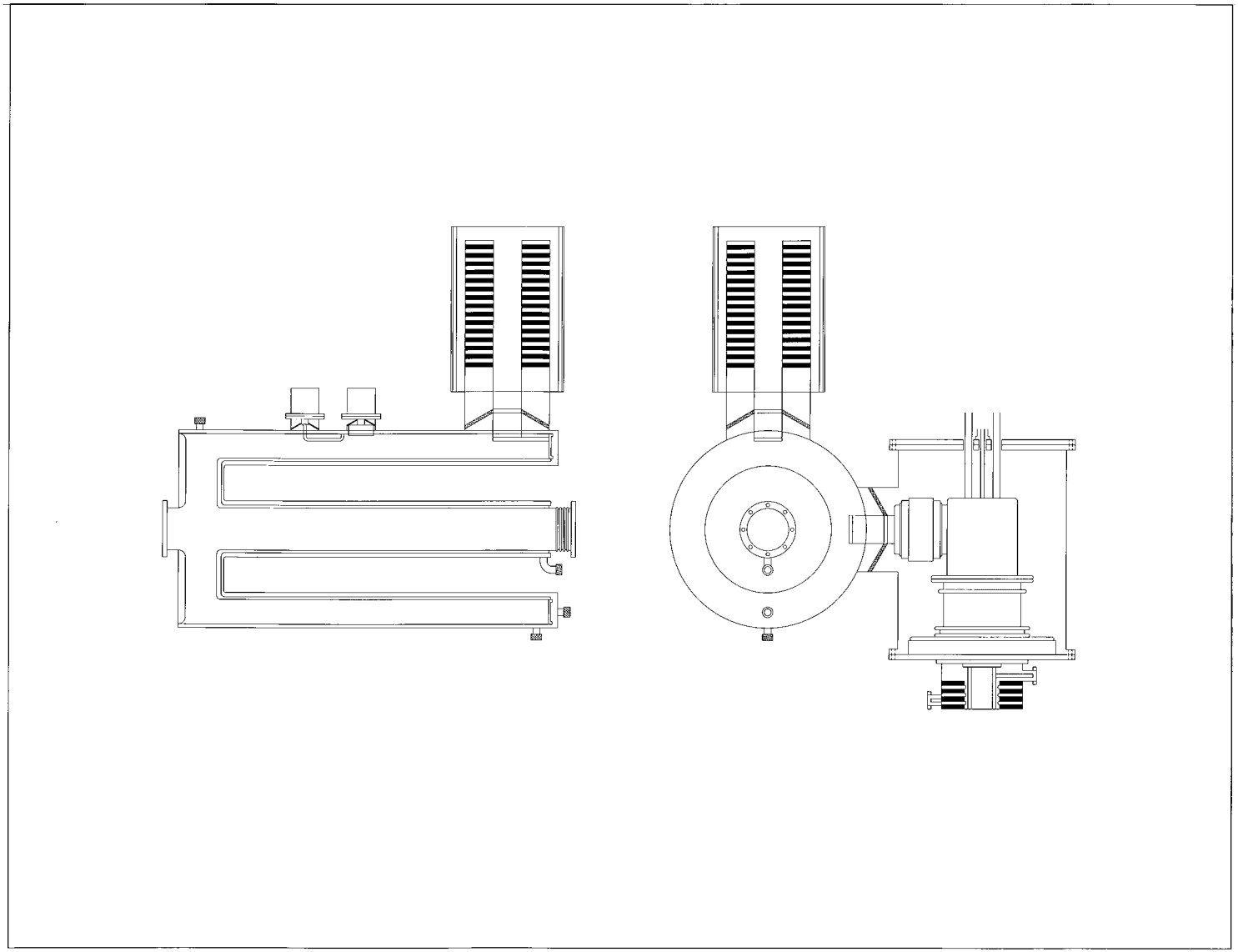

Figure 4 New Cavity and Power Amplifier

IV. R&D

- **In order to provide reliable power at these levels, an R&D program could begin immediately on both fronts.**

- **For the two amplifiers, modifying one of our spare MI cavities with the two amplifiers and operate it in our test station at MI-60 would be a first start. A 50 Kwatt driver would be necessary along with increased anode supply capacity would get it going. Some clever way to artificially load the cavity could be worked out for testing under high power conditions.**

- **For the new cavity and amplifier, a detailed design could start immediately, followed by fabrication. Testing would be done at the MI-60 test station. The 50 Kwatt driver along with the increased anode supply capacity from above would be sufficient for testing (basically same volts and amps required).**

- **Final testing would be carried out in the Main Injector's tunnel with beam.**