LIGO-T890033-00-R

59

List of 3/15/89

REPORT ON THE LIGO

RECEIVERS/FACILITIES INTERFACE

Electrical and Optical Feedthroughs for Phase A Vacuum Chambers

Andrew Jeffries Robert Spero Mike Zucker

9 March 1989
Version 1.1

Abstract

We specify the electrical feedthroughs and optical penetrations required by the current Phase A LIGO design. In cases where the design is incomplete, we present our best estimate of the component count, along with a probable range.

1 The Assumed Design

We take existing drawings as the basis for the beam conditioning, beam-splitter, and test mass chamber design. There are seven types of vacuum chamber or manifold in these drawings, and several functional units (such as shark detector or photodiode) replicated frequently within the chambers. In keeping with the concept of design modularity, feedthroughs are specified for each type of chamber, independently of how many chambers are used and of the details of the chamber function.

2 Description of Chambers and Functions of Components within Chambers

2.1 The Chambers

TM1 Test mass chamber for one test mass.

TM2 Test mass chamber for two test masses.

HAM Horizontal axis ("pill box") module. This vacuum chamber appears in single and double form in the drawings.

BS8 8-foot diameter splitter chamber.

BS12 12-foot diameter splitter chamber

MAN Test mass chamber manifold, 6 feet in diameter in current concepts. The manifolds will house optical levers for control of test mass alignment.

SAT Satellite chamber.

2.2 Receiver Functions Requiring Feedthroughs

Shark-1, Shark-6 One (or six) degree of freedom shark sensor and control. The best guess for the wire count assumes several shared grounds, and a minimum number of coaxial cables.

PD-1 Low-noise, wide-bandwidth photodetector, used for monitoring intensity and cavity phase.

PD-4/MM2 Quadrant photodetector, along with 2-axis motorized mirror mount. Used in combination with LD/MM2 for optical levers.

LD/MM2 Laser diode, including monitor for light-control feedback, along with 2-axis motorized mirror mount.

Motor-3, Motor-6 Motorized stages, including position encoders, for positioning along 3 (or 6) degrees of freedom. The suspension points of several mirrors and other critical components are controlled with Motor-6 in the best guess specification, and Motor-3 is frequently used for positioning lenses.

Ref-Int The interferometer for anti-seismic reference arms, to extend low-frequency performance. Two reference arms per test mass are assumed.

Vib-mon Three-axis seismometer and three strain gauges to monitor vibrations and other disturbances.

AA/BCU A module providing both automatic alignment and beam centering. We assume two quadrant photodiodes, and an integral optical lever.

TV A combination mode imager, phase camera, and mode matching monitor for automatic alignment system.

3 Electrical Feedthrough Requirements for Each Type of Chamber

Electrical feedthroughs are of two types: "Single", which is a single-conductor unshielded wire used for non-critical applications such as supplying current for motors and powering in-vacuo electronics; and "Coax", which is a shielded coaxial cable with isolated ground connection, for low level signals and shielding lines with modulation.

The entries for "No. Wires/Func." refers, for the example of Shark-6, the number of wires and cables needed for each sensing and controlling 6-axis shark detector. The entries are subdivided into estimates of minimum, best guess, and maximum wire counts. The "No. of Funcs." column refers, for example, to the number of suspended masses that require Shark-6's. The rightmost column, "Wire count" is the product of the best guess entries for *(a)* Number of wires/function and *(b)* Number of functions.

3.1 TM1—Chambers with One Test Mass Each

Drawing GAT2WA9 is used as a basis. We assume one Shark-6 and one Motor-6 per test mass, main steering mirror, and reaction mass. Shark-1 is for the anti-seismic reference arm, with two controlled dimensions per test mass.

Electrical Feedthroughs for TM1—One Test Mass VER 2.1											
	No. Wires/Func.						No. of Funcs.			Wire count	
	Single			Coax							
Function	min	bg	max	min	bg	max	min	bg	max	Single	Coax
Shark-1	4	6	7		2	5		2		12	4
Shark-6		21	42		12	30		3		63	36
PD-4/MM2		14			4		0	2	4	28	8
LD/MM2		14			2		0	2	4	28	4
Motor-3	9	18	38		0			1		18	0
Motor-6	15	36	74		0			3		108	0
Ref-Int		15			5		0	2		30	10
Vib-mon		3			6			1		3	6

3.2 TM2—Chambers with Two Test Masses Each

The feedthroughs are double the entries for TM1.

3.3 Horizontal-Axis Modules

The feedthrough requirements are based on drawing 89L-307, which uses 6-foot horizontal-axis modules with about five feet of usable length for component suspension, and two feet of usable width. We assume only one table per module.

The minimum Shark-6 count refers to a pickoff chamber serving two interferometers, and the best guess refers to an in-line beam conditioning optics module for one interferometer. The maximum estimates assume tightest packing of suspended components.

The PD-4/MM2 and LD/MM2 provide two functions: linking the tables in the HAM chambers, and providing optical levers for mode cleaner and other angle-critical components. The minimum numbers refer to two optical levers, as used in the 40-m prototype. The best guess allows monitoring of all six degrees of freedom of the tables.

3.4 8-foot Diameter Beamsplitter Chamber

We assume a general-purpose chamber, used for Site 1 and Site 2, Phase A and Phase B, that accommodates single or dual broadband recycling or single resonant recycling. Drawing 89L-300 is used as a basis. The function counts are for dual BBR, which requires the most sharks and is a probable Phase A configuration.

3.5 12-foot Diameter Beamsplitter Chamber

We assume two interferometers, both with resonant recycling, as in Drawing 89L-307. The PD-4 and LD counts are the same as for the HAM modules, with the addition of a reference optical beam defined by the interferometer test mass axes. Additionally, there is provision for 8 two-axis optical levers within the chambers to control the resonant recycling rings; the minimum entry assumes only 2 optical levers, as for dual broadband recycling.

3.6 Satellite Chambers

Again, Drawing 89L-307 is used as a reference.

3.7 6-foot Diameter Manifolds

The Manifold chambers house optical levers to control the test masses.

4 Multiplexing Electrical Connections

Wire counts may be reduced by multiplexing. In particular, motors are likely to be used only one at a time, and all the motors within a chamber can share power and readout lines if a switch network is installed in the chamber. It may also be possible to multiplex continuous low-bandwidth signals by using digital techniques.

5 Optical and Other Feedthroughs

LIGO designs call for a small number of explicit optical feedthroughs. All critical photodetectors are within the vacuum, and the preferred design for optical levers calls for laser diodes within the vacuum.

The facility mission requires that the Manifold is rarely (if ever) exposed to atmosphere, severely limiting access to components mounted within. Components requiring even infrequent adjustment, replacement, or service (as expected for the optical levers) may require extra-vacuum mounting, with optical viewports replacing the tabulated electrical feedthroughs. Alternatively, fiber feedthroughs may be used.

The detailed design will include several inspection ports per chamber, and optical quality windows for diagnostic beams. We believe the overwhelming bulk of the expense is tied up in electrical feedthroughs.

6 Summary of Feedthrough Requirements

The table below summarizes our best guess of the electrical feedthrough requirements for the Phase A, 2-site LIGO. We note that the cost of feedthroughs may be a significant fraction of the construction cost, and emphasize the need for reducing the unit cost by using customized large-scale techniques. By far the wire count is driven by the number of sharks.

Electrical Feedthroughs for TM2—Two Test Masses VER 2.1											
	No. Wires/Func.						No. of Funcs.			Wire count	
	Single			Coax							
Function	min	bg	max	min	bg	max	min	bg	max	Single	Coax
Shark-1	4	6	7		2	5		4		24	8
Shark-6		21	42		12	30		6		126	72
PD-4/MM2		14			4		0	4	8	56	16
LD/MM2		14			2		0	4	8	56	8
Motor-3	9	18	38		0			2		36	0
Motor-6	15	36	74		0			6		216	0
Ref-Int		15			5		0	4		60	20
Vib-mon		3			6			1		3	6

Electrical Feedthroughs for HAM VER 1.0											
	No. Wires/Func.						No. of Funcs.			Wire count	
	Single			Coax							
Function	min	bg	max	min	bg	max	min	bg	max	Single	Coax
Shark-6		21	42		12	30	10	14	20	294	168
PD-4/MM2		14			4		2	4		56	16
LD/MM2		14			2		2	3		42	6
Motor-6	15	36	74		0			1		36	0
Motor-3	9	18	38		0			4		72	0
PD-1		3			3			2		6	6
AA/BCU		4			14		0	1	2	4	14
TV		20			4			1		20	4

Electrical Feedthroughs for BS8 VER 1.0											
	No. Wires/Func.						No. of Funcs.			Wire count	
	Single			Coax							
Function	min	bg	max	min	bg	max	min	bg	max	Single	Coax
Shark-6		21			12	30		10		210	120
Motor-3	9	18	38		0			4		72	0
Motor-6	15	36	74		0			5		180	0
PD-4/MM2		14			4			9		126	36
LD/MM2		14			2			9		126	18
Vib-mon		3			6			1		3	6

Electrical Feedthroughs for BS12 VER 1.0											
	No. Wires/Func.						No. of Funcs.			Wire count	
	Single			Coax							
Function	min	bg	max	min	bg	max	min	bg	max	Single	Coax
Shark-6		21			12	30		18		378	216
Motor-3	9	18	38		0			8		144	0
Motor-6	15	36	74		0			10		360	0
PD-4/MM2		14			4			14		196	56
LD/MM2		14			2			11		154	22
Vib-mon		3			6			1		3	6

Electrical Feedthroughs for Sat VER 1.0											
	No. Wires/Func.						No. of Funcs.			Wire count	
	Single			Coax							
Function	min	bg	max	min	bg	max	min	bg	max	Single	Coax
Shark-6		21			12	30		4		84	48
Motor-3	9	18	38		0			2		36	0
Motor-6	15	36	74		0			3		108	0
PD-4/MM2		14			4			5		70	20
LD/MM2		14			2			4		56	8
Vib-mon		3			6			1		3	6

Electrical Feedthroughs for Manifold VER 1.0											
	No. Wires/Func.						No. of Funcs.			Wire count	
	Single			Coax							
Function	min	bg	max	min	bg	max	min	bg	max	Single	Coax
PD-4/MM2		14			4			6		84	24
LD/MM2		14			2			6		84	12

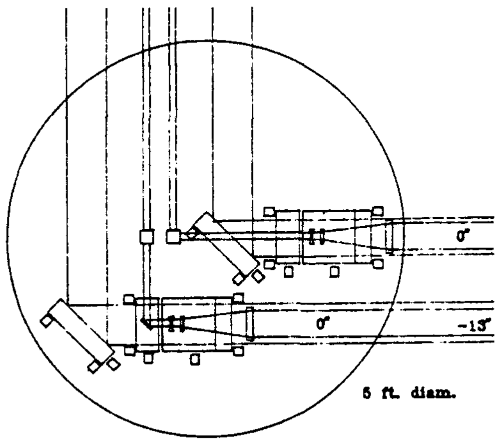
LIGO Electrical Feedthrough Requirements VER 1.0						
	Wires/Chamber		No. Chambers		Wire count	
Chamber	Single	Coax	Site 1	Site 2	Single	Coax
TM1	290	68	8	8	4,640	1,088
TM2	577	130	4	0	2,308	520
HAM	530	214	58	30	46,640	18,832
BS12	1,235	300	1	0	1,235	300
BS8	717	180	1	2	2,151	540
SAT	357	82	4	0	1,428	328
MAN	168	36	6	4	1,680	360
TOTALS					60,082	22,968

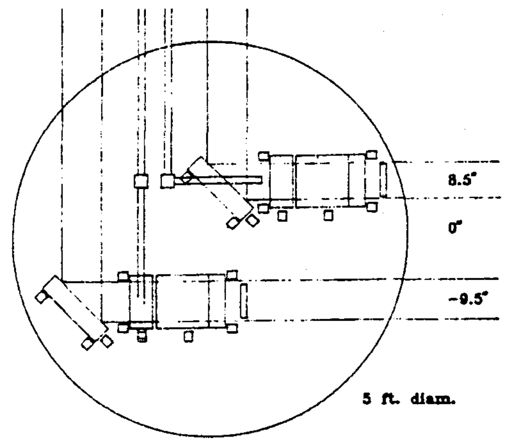
VERSION 2. Note - Drawing NOT Complete Yet. (1/10/89)

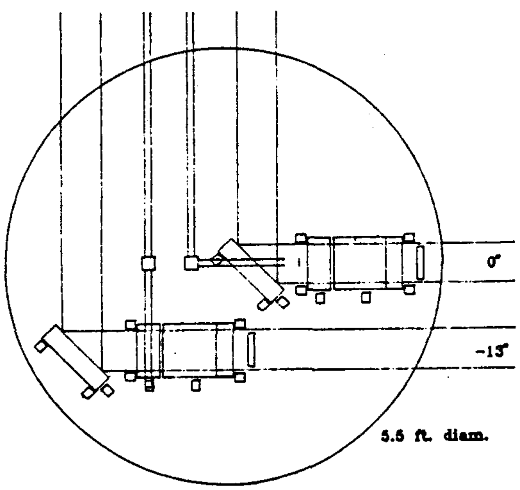
Suspension Block with Seismic Mirror Inset - Trials of Possible Mass Locations.
(All to same scale)

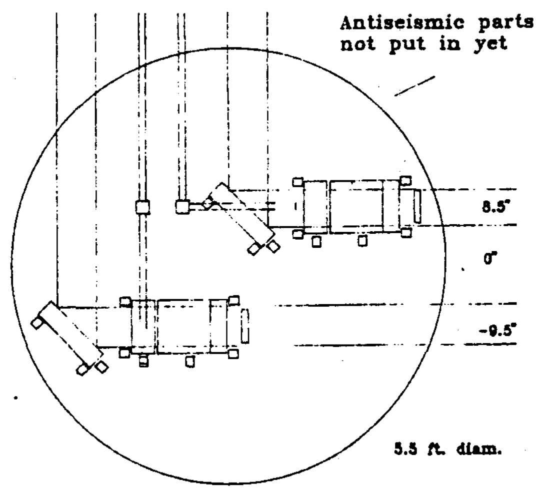
Version 2. Making some space for Antiseimic Refvearence Arms (where possible) and additional antiseismic beams.

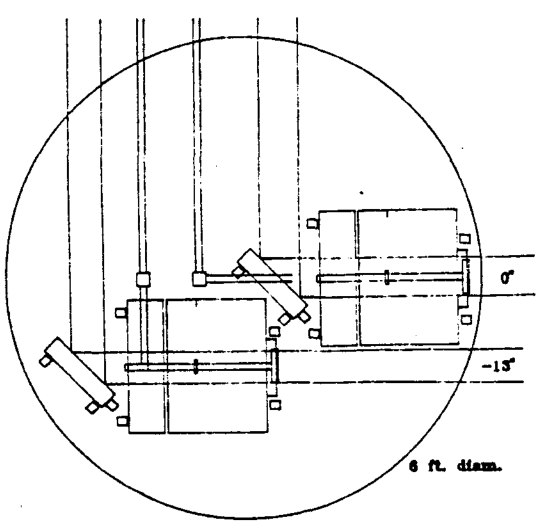
Highest Mass Locations | Lowest Mass Locations

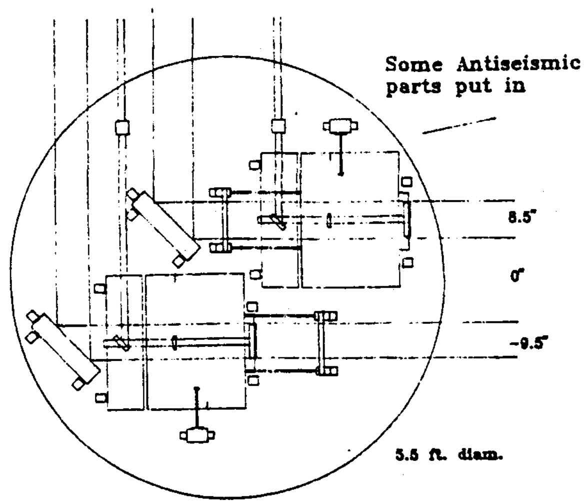




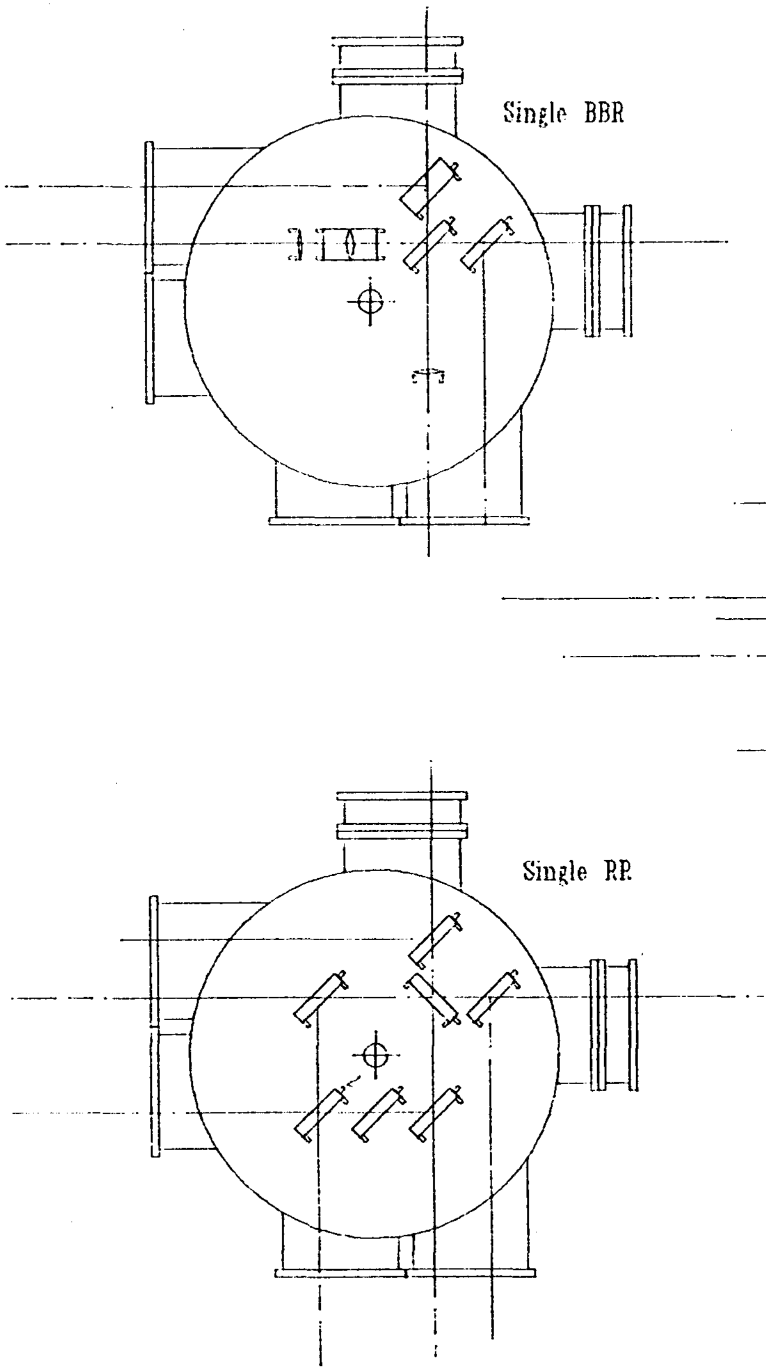


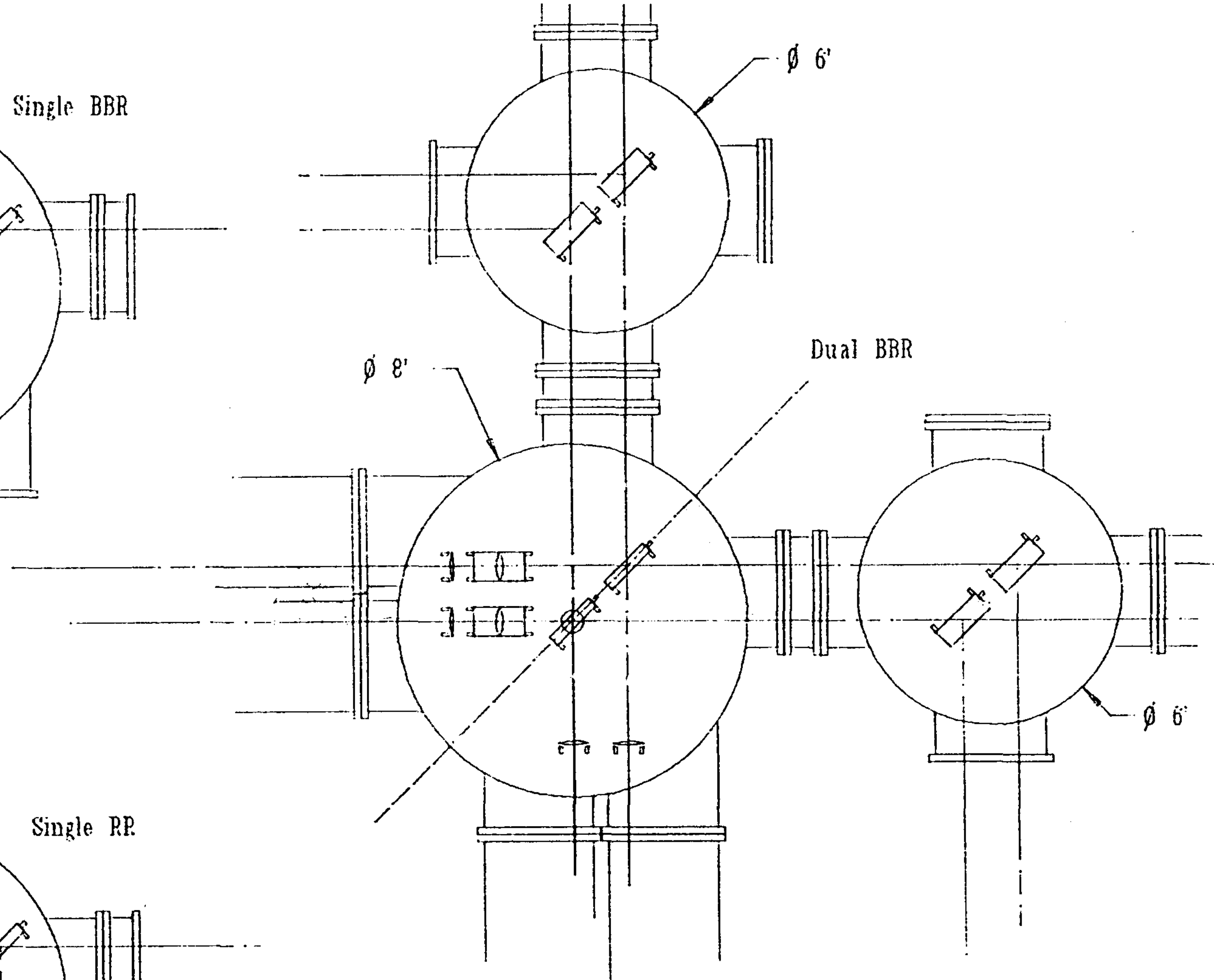




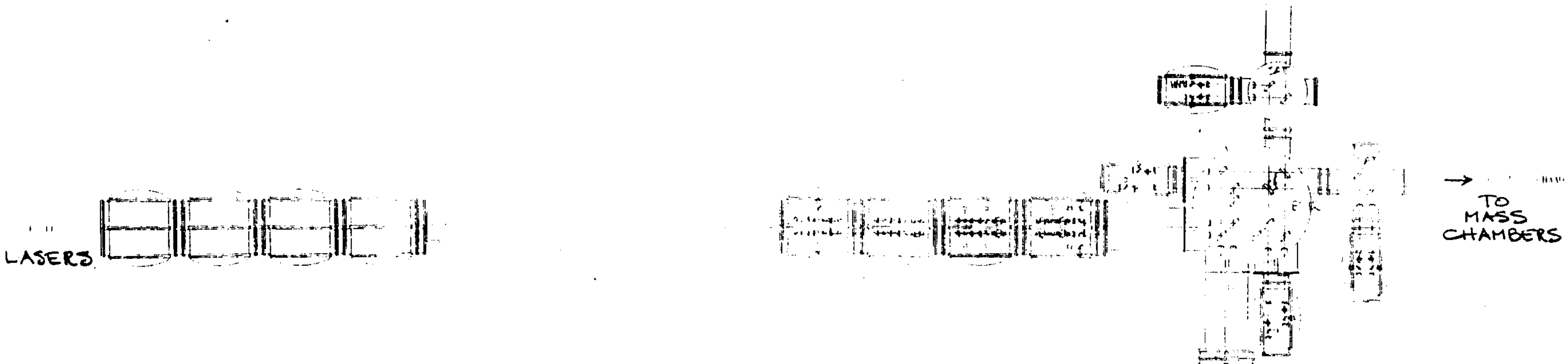


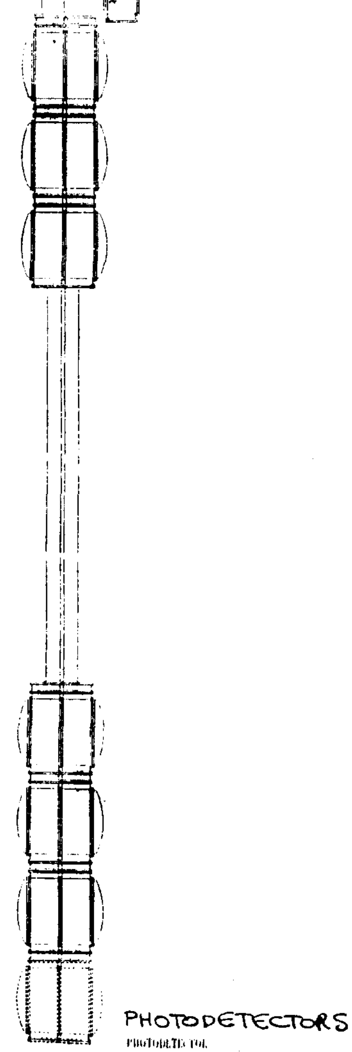
gat2wa9





TITLE: Universal Phase A Diagonal/Phase B Splitter Tank			PAGE: 1
DWG. NO: 89L-300	DATE: 3/3/89	LAST REV: 3/4/89	SCALE: 1:50
BY: M. E. Zucker			
MATERIAL: N/A			NO. REQ'D: N/A
Caltech/MIT LIGO Project	Account No. N/A		



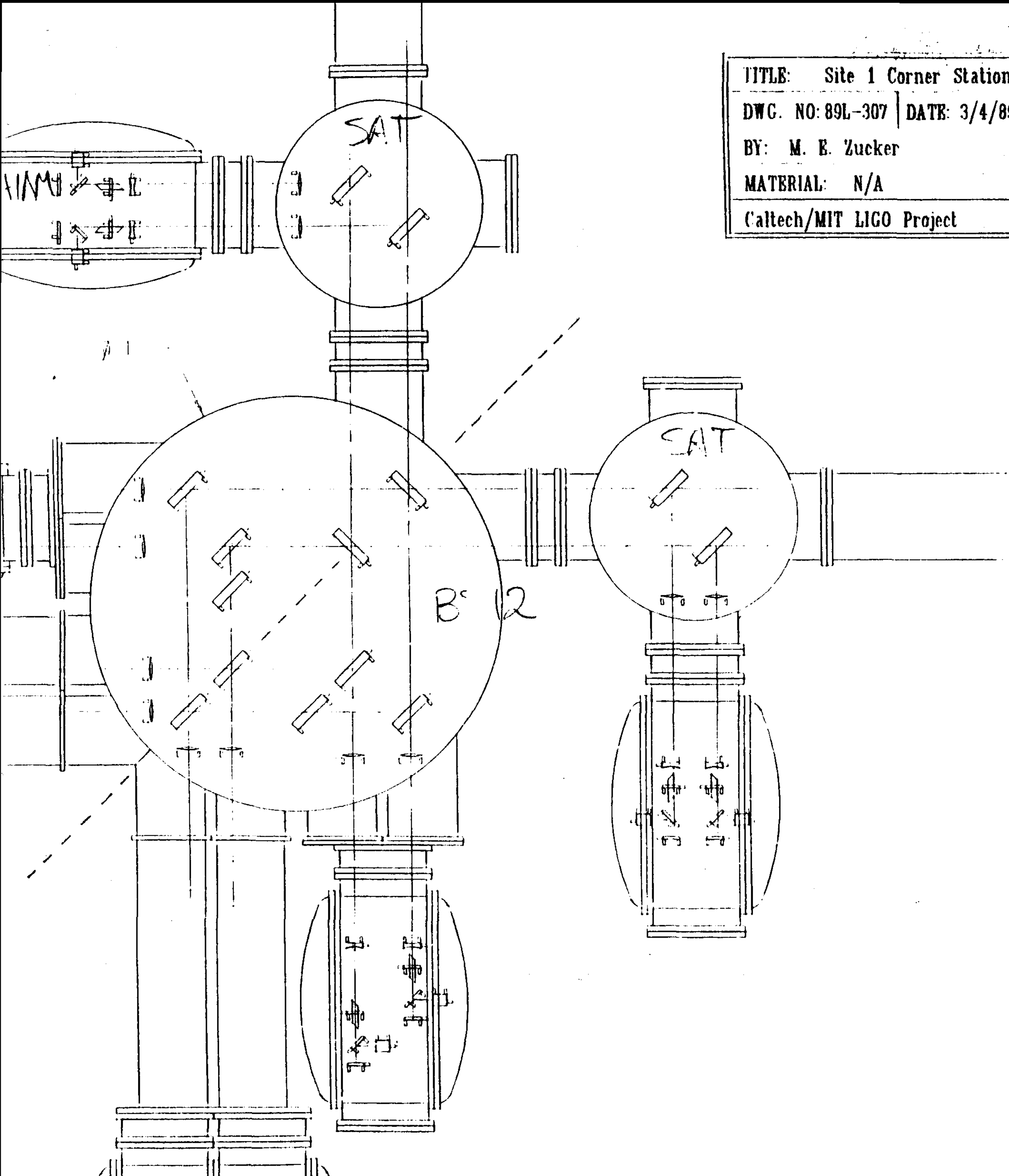


NOTE: THIS IS A MUCH-REDUCED COPY OF DRAWING 89L-307 TO SHOW THE OVERALL LAYOUT.

THE FOLLOWING 2 PAGES ARE FULL-SIZED COPIES OF THE PART OF THIS DRAWING THAT SHOWS CHAMBERS WITH OPTICS.

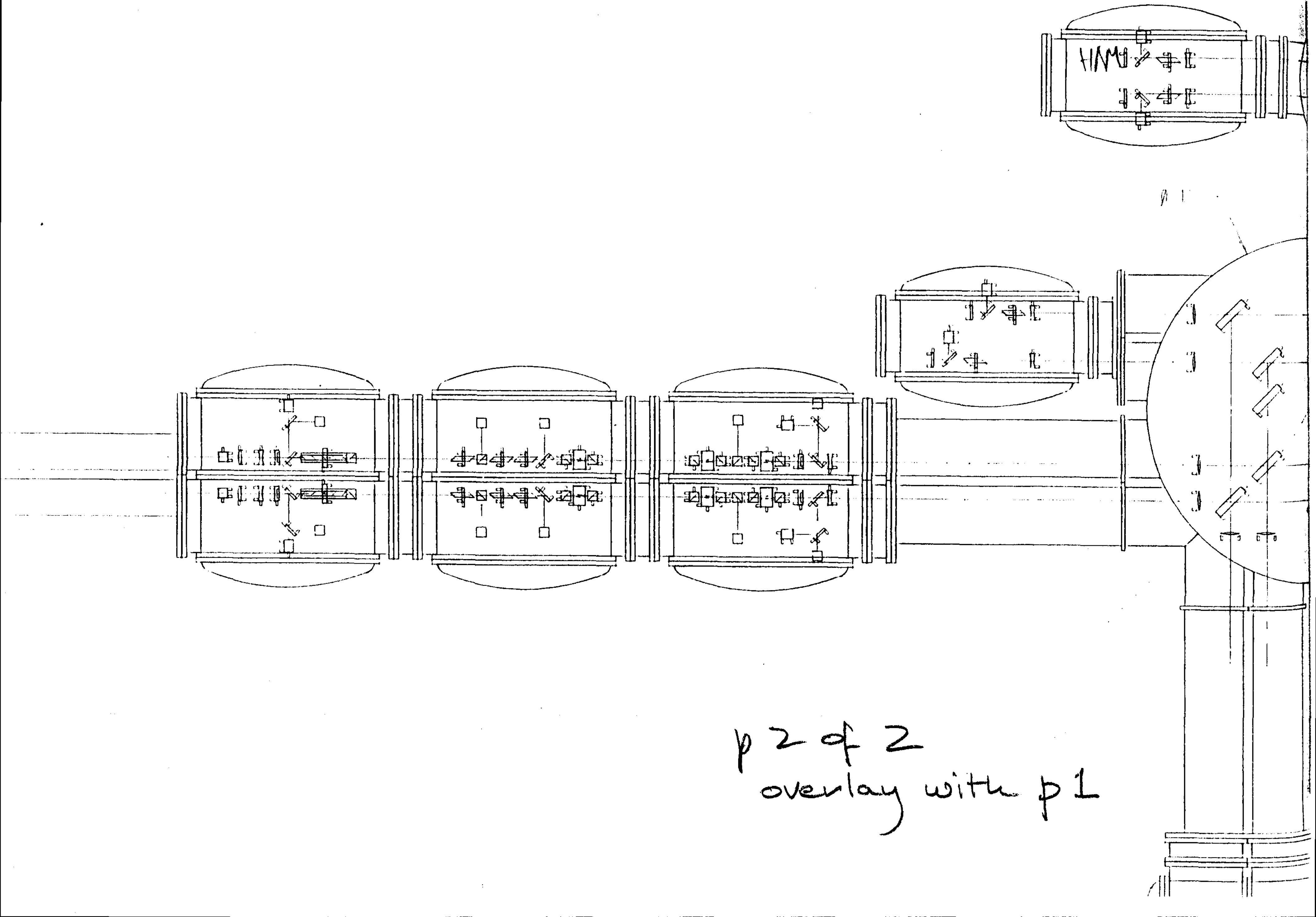
EJF
3/9/89

TITLE: Site 1 Corner Station; Dual RR Setup			PAGE: 1
DWG. NO: 89L-307	DATE: 3/4/89	LAST REV: 3/6/89	SCALE: 1:50
BY: M. E. Zucker			
MATERIAL: N/A			NO. REQ'D: N/A
Caltech/MIT LIGO Project		Account No. N/A	



→ TO MASS CHAMBERS

p 1 of 2
overlay with p2



p 2 of 2
overlay with p 1

BATCH START

STAPLE

OR

DIVIDER

From SAULSON@gravity.mit.edu Thu Mar 2 12:43:26 1989
Subject: receiver-facility interface
To: robert@ligo.caltech.edu
X-Vms-To: IN%"robert@ligo.caltech.edu"

Dear Bob,

I wrote this outline a while ago. Please use it as you see fit when you committee works on the topic next week.

Best regards,
Peter

Receiver/Facility Interfaces -- Outline
Draft January 25, 1989 PRS

At tanks:

- electrical wiring, numbers of wires, arrangement on ports
  - shielded /BNC
  - instrumentation (multipin)
  - HV, (high current?)

- optical access
  - optical quality viewports, size, number, location, UV transmission
  - utility viewports, size, number, location
  - optical fiber feedthrus, number of fibers, types of fibers

- mechanical interface
  - free volume, shape and size
  - access locations, sizes
  - beam locations (including anti-seismic beams, optical levers) (or is this too receiver-specific?)
  - mounting hardware configuration
  - weight limits (imposed by external isolation or by elevator mechanism)
  - degree of external vibration isolation, or predicted noise spectrum

- external electronic instrumentation
  - style-- NIM, CAMAC, etc.
  - space available, number of modules
  - utility power at which voltages, degree of regulation
  - HV
  - dedicated high current supplies?
  - cooling -- convection, fans
  - cabling to tank feedthrus
  - shielding, esp. RF
  - grounding strategy

- external optical equipment
  - optical benches -- number, size, location
  - connection to tanks -- periscopes, fibers in trays, externally attached evacuated spaces for UV?

- external mechanical equipment
  - cranes -- number, weight limit, speeds, max. acceleration, access to floor area and tanks
  - clean fork lifts or lab jacks

scaffolding or false floors for personnel access
strategy for storage of removed tank lids, port covers, etc.

vacuum interface
- installed pumping speed (or allowed gas load)
- pump types
- expected pump-down time
- valves -- number, size, location
- back-fill strategy, including access time
- list of forbidden materials, if any

cleanliness
- clean benches -- number, size, location, cleanliness
- in-tank covers
- in-tank cleaning strategy

In vertex building: (all of the above, plus:)

Lasers
- type, power, number, location, quality

or should we treat lasers as part of receivers, and instead spec:

Laser facilities
- bench space, location, mechanical quality
- electrical power available
- cooling water available (temp, flow rate, water quality)

General lab space
- size, location, power available,
- access to interfs for personnel, optics, electrical sigs

Communications, Control, Housekeeping and Auxiliary measurements, Recording

Voice communications
- between control room, vertex area, remote stations
- between sites

Analog signals
- between control room, vertex area, remote stations?
- sheilding, bandwidth, number of signals

Digital signals
- Protocol
- Hardware
- number of channels, bandwidth, inbound vs. outbound

Off-site communications
- to other site(s)
- to home institutions, user institutions

Computers
- type, operating system, bus, software, display
- interface between receiver, housekeeping, recording
- degree of distributed computing
- control -- bandwidth, number of channels
- A/D and D/A specs

Auxiliary Measurments

sensor types, sensitivity, bandwidth, locations
capacity for additional receiver-specific measurements

Recording

medium, bandwidth, capacity
Receiver/housekeeping interleaving
configuration control (how do we know which channel is
which signal?

#59b

List of 3/15/89

TO: Althouse and Franzgrote

FROM:RW March 13,1989

CONCERNING: Receiver/Facility Interfaces

The document "Electrical and Optical Feedthroughs for Phase A Vacuum Chambers" is a fine beginning to a much larger job of defining the receiver/facility interfaces.

Specific comments on the document:

1) It is likely that we will be using optical fibers in position sensors and possibly in laser monitor and servo monitor channels. Provision should be made for optical fiber feedthroughs on the tanks. I could imagine as many as 5 percent of the signal channels being optical fibers.

2) The final controllers for the fringe lock will most likely be electrostatic so that for the test mass servoes it is necessary to specify high voltage breakdown voltages for the connectors and wires. If the system is designed, as that now under development here, it will require 8 unshielded connections able to handle upto 2 kilovolts to ground per test mass.

Partial list of other Receiver/Facility interface concepts that will need to be addressed.

ELECTRICAL AND OPTICAL

1) The number and quality of signal and instrumentation lines between tanks and between buildings.

2) The grounding and shielding strategy within tanks and between tanks.

3) The digital lines and ports needed. Where will the analog to digital conversions take place, the number of analog to digital interfaces, at each tank or in each building?

4) Should there be local or global power supplies for analog and digital electronics?

5) Internal wiring of the tanks - patch panels, standardized connectors

6) Number of viewports

7) Number and optical quality of injection ports

8) Standards for instrumentation and digital electronic modules - NIM, Camac, etc.

MECHANICAL INTERFACES

1) Internal structure of the tanks and attachment of receiver assemblies. Type of kinematic supports, loads anticipated.

2) Is there need for mechanical motion feedthroughs?

THERMAL INTERFACES

1) Power dissipated in tanks.

2) Cooling of components in tanks ; radiative only? conductive with heat straps to the outside?

BATCH START

STAPLE
OR
DIVIDER

#59c

List of 3/15/89

To: LIGO Project
From: PRS March 13, 1989
Re: Report on Receiver-Facility Interface

I think the committee turned out a very useful document. I share the worry expressed in RW's memo that not enough topics are covered to completely specify the interface.

I had written an outline of what I thought might go into such a complete specification. I had in mind some NASA interace documents I had seen, and tried to imagine what we would need to tell an outsider (or ourselves) how to design an interferometer to fit in the facility.
It is attached below. This is not to say that RS, MZ, and AJ should have tried to cover all these topics last week. Some of the topics more likely belong in a Data Committee report, others in Support Facilities or maybe even Environmental Specs. We just need to be sure that by the appropriate time we have thought about all of the important issues.

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Draft January 25, 1989 PRS

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- valves — number, size, location
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- list of forbidden materials, if any

cleanliness
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Communications, Control, Housekeeping and Auxiliary measurements, Recording

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- between sites

Analog signals
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- sheilding, bandwidth, number of signals

Digital signals
- Protocol
- Hardware
- number of channels, bandwidth, inbound vs. outbound

Off-site communications
- to other site(s)
- to home institutions, user institutions

Computers
- type, operating system, bus, software, display
- interface between receiver, housekeeping, recording
- degree of distributed computing
- control — bandwidth, number of channels

A/D and D/A specs

Auxiliary Measurments

sensor types, sensitivity, bandwidth, locations
capacity for additional receiver-specific measurements

Recording

medium, bandwidth, capacity
Receiver/housekeeping interleaving
configuration control (how do we know which channel is which signal?