CIST....
CORRTEX INTERFEROMETER SIMULATION
TEST

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CIST...

**CORRTEX INTERFEROMETER SIMULATION
TEST**

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Introduction

CIST stands for CORRTEX Interferometer Simulation Test and was conducted over a one-month period from August 15, 1994, to September 20, 1994. In CIST we detonated 8 meter lengths of 5.1 cm ID PVC pipe filled with unsensitized liquid Nitromethane. The resulting explosion was used to crush CORRTEX and RF Interferometer sensor cables which were placed inside the PVC pipe or taped to the outside of the pipe. Fig. 1 shows a schematic of the CIST layout. Fig. 2 shows a drawing of the typical pipe and filling "T" arrangement. Appendix A shows a schematic of every test.

In this report we summarize some of the information that we obtained on CIST. The complete data analysis of CIST will be accomplished as time allows.

Purpose

With the cessation of nuclear testing we wanted to be able to perform some final tests to validate and cross calibrate the RF Interferometer on which we had been working for several years. This purpose was combined with the aim of helping the NTS and Livermore personnel to maintain their state of readiness should testing resume. As the planning for CIST progressed other aims became evident:

1. Measure the dynamic temporal response of the cavity pressure system that was used on Galena and on the Non-Proliferation Experiment.
2. Test the pin strings that were to have been used on the Greenwater event.
3. Find a low crush-threshold cable that we could use in future tests with high explosives.
4. Allow the Los Alamos National Laboratory Treaty Verification group to test their RF CORRTEX and CINAPS systems under realistic conditions.

CIST was fired using the LLNL facilities at hole U9ct at the Nevada Test Site. The natural 5 meter drop in elevation across the Yucca fault was used to provide a berm for additional protection from the blast wave and from shrapnel. CIST was fielded by LLNL with electronics support provided by EG&G/LVO and mechanical engineering support provided by EG&G/AVO. The detonation explosives and arming and firing were provided by Sandia National Laboratory. Both arming, firing and diagnostic recording were done in Trailer 985. LANL CORRTEX recording was done in a Treaty Verification program Hydrodynamic Recording Facility.

Personnel

Test Director.....	Bernie Roth	Livermore Advisor	
Project Physicist.....	Ray Heinle	(and originator).....	Ray Cornell
C&D Engineer.....	Don Ecker	PhaSyR Development	
EG&G/AVO ME.....	Mel Hatch	LLNL PhaSyR.....	Hal Goldwire
Sandia A&F Engr.....	Ray Peabody	EG&G/LVO EE.....	Robin Robinson
	Harold Roberts	LANL CORRTEX	
EG&G/LVO EE.....	Bill Webb	LANL EE.....	Keith Alrick
	Paul Tanner	EG&G/LVO.....	Tom Graves
	Ken Adams	Photographic Support	
	Tony Coleman	EG&G/LVO.....	Bill Garcia
	Len Szeszycki		Larry Arnold
	J. R. Thompson		

The Explosive

The explosive was Nitromethane (CH_3NO_2). Nitromethane is not a highly sensitive explosive under ordinary conditions but can be made to detonate if a strong enough shock is used to initiate the blast. This explosion will propagate down thin-walled (i.e. untamped) pipes of diameters greater than about two cm. Small amounts of chemical additives can be used to make the nitromethane more shock sensitive, however, for simplicity and safety we chose to use unsensitized nitromethane. A detonator booster arrangement designed by Paul Cooper of SNL reliably ignited the nitromethane for every test. Fig. 3 shows a detail of the detonator/booster arrangement.

The detonator was fired from the recording trailer using a SNL standard fireset. The safety precautions (arming and firing procedure) were similar to those used to arm a nuclear device. The explosive and operational safety procedures are outlined in reference 1. These safety procedures were followed exactly under the auspices of the LLNL Test Director and LLNL Health and Safety.

Explosive Performance

In total, thirteen shots were fired using the entire contents of one 55 gallon drum of nitromethane. Each shot except for the first and last used about four gallons of liquid explosive. The first shot, used about one gallon and the last shot used somewhat more since the remaining nitromethane was poured into a standpipe in the filling tee.

The explosive fired reliably every time. The approximate time interval from bridge-wire activation to shock arrival at the front surface of the nitromethane was about 19 μsec (obtained by bringing a sensor cable close to the detonator cable to pick up the high bridge wire current). Detonation speed was constant between tests and over the length of the eight meter PVC pipe. (See fig. 4) The average detonation speed for all the CIST tests was about 6.2 km/sec. Short order variations in detonation velocity of about 0.7 km/sec were noted but further analysis may show this to be cable crush noise. (See Fig. 5)

Cable-Interferometer Tests

The basic geometric layout for the CORRTEx and interferometer cables on CIST was laid out by Ray Heinle and Hal Goldwire early in the design stages of CIST. The basic test objectives were to gain experience and test the performance of the PhaSyR interferometer and to test cable crush properties for various cable types and geometries. LANL also supplied input to the design of the 13 CIST shots.

In a CORRTEx measurement the two way transit time of reflected probe pulses is measured with an accurate time-interval meter and the cable length is deduced from those data, knowing the cable propagation velocity. In the RF Interferometer a sinusoidal probing signal is sent down to the sensor cable. The shorted (or open) end of the cable reflects the wave back to the recording trailer. The reflected wave is separated from the incident signal and recorded by either a single 8 or 12 bit digitizer that is phase-locked to the incident probing signal. The digitizer thus records the phase shift in the return signal of the cable being crushed by the explosion (detonating nitromethane in the case of CIST). We call the RF interferometer a PhaSyR (Phase Synchronous Reflectometer).

The fixed reflections (connectors, etc.) that would interfere with the measurement are determined by briefly turning off the probing signal and observing the timing and amplitude of the returning reflections from each source (each connector and the end of the cable). Phase correction circuitry can be adjusted to compensate for the bulk of these reflections canceling out the fixed reflections as the data are recorded. Data reduction procedures correct for the effect of the remaining spurious reflections. Fig. 6 shows the four phases that we record and the gated calibration signal. Fig. 7 shows the effect on the data of these fixed reflections.

The eight and twelve bit interferometers that we used on CIST were both manufactured by DSP Technology and were identical except for the actual digitizer. Fig. 8 shows a comparison between the CORRTEx and the eight bit interferometer.

The CORRTEx data (the triangles) is much sparser than the interferometer. The interferometer does have some periodic noise that may be due to stray pickup in the recording station. The overall sampling period employed for this test is one point every 320 nanoseconds for the interferometer and one point every 12 microseconds for CORRTEx. This sample rate improvement is especially important for obtaining good first crush (and hence accurate location of the energy center) in a satellite hole geometry such as would have been used on TTBT experiments.

Cable Types

Eleven cable types were tested on CIST:

1. FSJ1-50 (a 1/4 inch foam dielectric cable)
2. FSJ4-50 (a 1/2 inch foam dielectric cable)
3. RG-174 (1/8 inch solid dielectric cable)
4. RF-174 (1/8 inch foam dielectric cable)
5. Dual RF-14 (Dual 1/2 " cable)
6. RF-214 (Braided shield, solid dielectric)
7. Twisted pair ethernet cable
8. Microdot 250 (small Teflon dielectric cable)
9. HJ-4 (1/2" air dielectric cable)
10. Computer ribbon cable
11. RG402 (1/8" solid center, solid shield semi-rigid cable)

The emphasis was on finding small light cables with a low crush threshold. Unfortunately, none of the cable types proved to be perfect in this regard but RF-174 proved to be a winner for most purposes. Unfortunately RF-174 is only available by special order from the manufacturer and from a small amount in the LANL inventory.

Many of the cables (such as RG-174) proved to be too noisy. Others, like twisted pair, had distributed phase error problems that would render them difficult to use (fig. 9).

Crush Threshold Tests

For future uses of the RF interferometer in high explosive tests it was desirable to find cables that crushed easily. In searching for sensitive cables we used a water jacket to propagate the shock wave out from the nitromethane and shock cables at increasing distances from the central cylindrical source, i.e., the 5.1 cm PVC pipe filled with exploding nitromethane. Tests 2 and 11 were designated for this purpose and the nitromethane-containing pipe was surrounded with a 60 cm pipe filled with water. In test 2 the detonation wave was to have been started in a 5.1 cm section of pipe, then necked to down to 1.9 cm inside the water jacket. This would have produced a sufficiently weak shock to have tested the crush threshold of the cable types in the test. Unfortunately the detonation wave extinguished as it went into the 1.9 cm pipe. Test 11, which originally was to have used a 1.9 cm pipe to get the desired weak shock was reconfigured to use a 5.1 cm pipe along its entire length.

Test 11 performed well although the shock wave was too strong to test the crush threshold of the more sensitive cables. These data are still being analyzed.

A second method for estimating crush threshold was to run the cables through air away from the nitromethane pipe at 90 degrees; as the cable got further way the airborne shock strength decreased rapidly. Blast wave reflections off the

ground and sandbag supports tended to make the shock wave stronger and thus the shock pressure was difficult to calculate. These data are still being analyzed.

Los Alamos National Laboratory Participation

A Los Alamos National Laboratory Hydrodynamic Recording Facility (HRF) was used on CIST by EG&G/LANL personnel to record various cables they installed on the CIST sources. The LANL crew participated on all tests, recording some of the LLNL cables when possible. All results of these tests are being shared fully between the two organizations; the raw data were exchanged immediately after each test.

A new eight bit "RF CORRTX" designed by Keith Alrick of LANL was tested by the EG&G/LANL crew. This interferometer is similar to the LLNL design but it employs somewhat different sampling philosophy and uses Lecroy digitizers instead of the DSP units used by LLNL. Fig. 10 shows a comparison of the three interferometers that were used on CIST: the LLNL 8 bit, the LLNL 12 bit and the LANL 8 bit. It appears that the LANL design is less subject to the high frequency noise that is evident on the LLNL design. This is, perhaps a consequence of the LANL interferometer being more completely packaged and integrated as opposed the Livermore units that were basically in a breadboard state. The additional external wiring in the LLNL units may have served as antennas for noise pickup.

LANL also used standard CORRTX-III recorders in conjunction with the CINAPS Treaty Verification control system. These units are an integral part of each HRF.

One of the aims of the LANL participation in CIST was determining the precise detail of the cable crush and the way the interferometer perceives the phase changes at the shock interface. According to Brad Wright of LANL (Ref. 2) we should be able to note differences in the interferometer signature depending on the position along the probe wave that the cable is initially crushed. These data are still being analyzed.

Blast Overpressure Gages

In preparation for the BEEF certification series two PCB model 137A12 overpressure gages were used to monitor the blast pressure at various distances from the explosive charge.

The sensors were recorded by DSP 8 bit digitizers, analog magnetic tape, and MERS (Multiple Event Recording System). Figs 11 and 12 show the layout of each test on which the overpressure gages were used. Fig. 13 shows a composite of the two gages, OP1 and OP2 that were used. On this test, OP1 was about 15 meters from the source and OP2 was about 25 meters from the source.

Mers (Multiple Event Recording System)

The MERS was purchased from and developed by DSP Technology for use by Special Measurements to record motion data. MERS fills the gap between the maximum recording rate of SMIDS (80 samples/second) and the DSP TRAQH digitizers which can record up to 200 Msamples/second. Also SMIDS is highly specialized for use by Containment Program. MERS, on the other hand is a general purpose data acquisition system. MERS is a true digital replacement for analog recording tape. With MERS the data is digitized with a 12 bit A/D converter and then recorded on a magneto optical drive in real time. Up to 64 channels at 5 ksamples/second (or correspondingly faster if there are fewer channels) can be recorded. MERS was used to record pressure gages from the Cavity Pressure system and the BEEF overpressure gages. MERS performed well on all CIST tests.

Cavity Pressure Tests

We tested the basic cavity pressure system that was fielded on Galena and was to have been used on the Gabbs event. The unit used on CIST was actually used and recovered from the Non-Proliferation Experiment (NPE). In the LLNL design for a cavity pressure experiment, the sensor tube is pre-pressurized to about 1500 psig with a relatively incompressible fluid (water, or a water/glycol mixture). When the sensor tube ruptured, the high pressure fluid escaped and prevented crushing or sealing off of the tube. The nitromethane explosions were used to rupture diaphragms that were of the same design fielded on the NPE. The explosions were also used to directly rupture the steel pressure sampling tubes.

We tested the dynamic system response using a rubber hose leading to the steel sensor tube. In addition we tried an arrangement consisting entirely of steel tubing as was done on most cavity pressure experiments before Galena. Fig. 14 shows a comparison between the rubber hose results and the steel tube results. The steel tube response was much faster.

Three sets of liquid pressure transducers were used on for the Cavity Pressure system that we tested on CIST:

1. The standard PED IV/Cavity pressure transducers were recorded at the normal 80 sample per second rate that the PED IV multiplexer uses. (Channels 51A and 51B)
2. A pressure transducer (Channel 51D) was located where the sensor tube entered the cavity pressure package. This transducer was recorded at 50 ksamples/second by MERS, by a DSP TRAQH digitizer, and on analog magnetic tape.
3. A pressure transducer was located about 3 meters from the explosion, (protected by sandbags). This is channel 51C. Fig. 15 shows an overlay of two of these transducers, 51C and 51D. Channels 51A and 51B which were digitized at 80 samples/seconds

are not shown. They are identical to channel 51D except for the slower recording rate. Fig. 16 shows an overlay of channels 51A, B, and C as recorded by the analog tape recorder and digitized by the EG&G/LVO Analog Data Center.

We expect the results of these tests to aid in the interpretation of older cavity pressure data. We have never performed such extensive tests to measure the dynamic response of the cavity pressure system.

Psp (Pin Shock Profile)

The PSP experiment, designed by Goldwire and Robinson was to have determined the shock wave gradients in the emplacement hole stemming column above a nuclear test, Greenwater in this case. These gradients are believed to affect hydrodynamic yield measurements in an emplacement hole. Since Greenwater was never fired, the PSP system had never been tested. This we did on CIST.

The PSP used a string of piezo-electric pins, each encased in a copper pipe, which were multiplexed together and then used to drive an optical transmitter for fiber optic data transmission to the recording station. In the recording trailer the signals were passed through an optical receiver and then recorded on DSP digitizers and magnetic tape.

We tested the PSP pin strings on two of the CIST tests and the pins worked well. Fig. 17 shows the raw data from one of those tests. Fig. 18 shows a plot of the pin times as a function of position, overlaid with a straight line fit to the data.

High Speed Camera

We made high speed color movies of each test using a 16 mm Fastax camera borrowed from Johnson Controls. These cameras, which were operated by Bill Garcia and Larry Arnold of the EG&G Consolidated Photo Group, were shot at 1000 frames/second for the first three tests; tests 4-11 were shot at 2000 frames/second and tests 12 and 13 were shot at 3000 frames/second.

These cameras recorded detonation progress and ejecta paths. Even though the entire explosion took place in about 1.5 msec., the cameras were sufficiently fast to capture several frames over the detonation duration of each shot, not to mention the spectacular fireball from each firing. The cover of the report shows two frames from these high speed recordings.

Acknowledgments

We would like to thank the personnel of the Sandia National Laboratories for their excellent support in providing the expertise and safe handling for the high explosives that we used in these tests. We particularly would like to thank Dr. Paul Cooper of SNL for his advice and calculations leading to the 100% successful set of detonations.

Conclusion

We have listed above some of the information gleaned from the CIST test series. To gather these data required much equipment setup, buildup of sensors, connection of cables, checklists, at least one "dry run" for each test, etc. The work was fast-paced, requiring rapid turnaround between tests, providing much operational practice.

Reference 3 is the final EG&G Field Operations Division test report for CIST. Reference 4 summarizes the various diagnostics on CIST performed for LLNL by EG&G. Table 1 briefly summarizes most of the experiments that we performed on CIST.

Table 1 CIST Summary

Test	DATE	Time	LLNL Cables	LANL Cables	Cav. Press.	Overpress. Gages	HS Cam.	PSP
1	8/15/94	1030	3	3	-	-	1000 fps	-
2	8/16/94	1230	3	3	-	-	1000 fps	-
3	8/17/94	1015	5	3	Hose 0" C	-	1000 fps	-
4	8/23/94	1010	4	2	Hose 1" C	-	2000 fps	-
5	8/24/94	1010	3	3	Hose 2" C	-	2000 fps	1
6	8/25/94	1000	4	3	Tube 3" C	-	2000 fps	-
7	9/7/94	1015	5	3	Tube 3" C,D	-	2000 fps	-
8	9/8/94	930	4	2	Hose 3" C,D	2	2000 fps	-
9	9/8/94	1435	3	3	Hose Cap C,D	2	2000 fps	-
10	9/13/94	920	4	2	Hose Wrap C,D	2	2000 fps	-
11	9/14/94	1210	6	2	-	2	2000 fps	-
12	9/15/94	1055	5	3	Tube Cap C,D	2	3000 fps	1
13	9/20/94	945	4	3	Tube Wrap C,D	2	3000 fps	-
			Total	88	C gage 6 m from explosive D gage 100 m from explosive			

The exercise gathered "real" data and was a great moral booster for all involved.

References

1. OSP-N-41 Special Operating Safety Procedure for CORRTEx/Interferometer Simulation Test (CIST), D.C. Ecker, Jr., May 17, 1994
2. Brad Wright, Los Alamos National Laboratory, private communication to Hal Goldwire, May 1994.
3. Bill Webb, EG&G Energy Measurements, *FIELD OPERATIONS DIVISION FINAL TEST REPORT FOR THE CORRTEx/INTERFEROMETER SIMULATION TESTS (CIST)* November 1994.
4. Bill Webb, EG&G Energy Measurements, *FIELD OPERATIONS DIVISION PHYSICS/INSTRUMENTATION FOR THE CORRTEx/INTERFEROMETER SIMULATION TESTS (CIST)*, November 1994.

We will detonate 8 m long PVC NM pipes from TRL 973

Fig. 1

The basic layout for each CIST test. The 100 m distance between the firing location and the recording station insured that peak overpressures were less than 0.5 psi. The pressure calculation ignores the additional protection provided by firing below Yucca fault, thus preventing any direct LOS between the trailers and the firing area.

13		2" SCD 80 PVC X 1.9 M LONG	1
12		2" SCD 80 PVC X 30 CM LONG	1
11	3530-020	COUPLING, 2 X 2 NPT, SCD 80 PVC	1
10	FIG 039-528	RECUCER BUSHING, 4 X 2" SCD 80 PVC	2
9	3505-020	TEE 4 X 4 X 4, NPT-F, SCD 80 PVC	1
8	3661-256	PIPE NIPPLE 2" SCD 80 PVC X 4" LONG	1
7	ECG94-201071	PLATE, END - CIST (PVC)	1
6	3862-020	2" FLANGE GASKET, TEFLON COAT, RIB	1
5	3852-020	FLANGE, SCD 80 PVC	1
4	EDG94-201044	COVER, ADAPTER, BOOSTER - CIST	1
3	EDG94-201040	END CAP, BOOSTER - CIST	1
2	EDG94-201039	ADAPTER, BOOSTER - CIST	1
1		2" SCD 80 PVC PIPE X 6.096 M (20FT) LONG	1
ITEM	P/N	NOMENCLATURE	QTY

CIST TESTS 3 THROUGH 10, 12 & 13 CONFIGURATION

4/26/94
M. HATCH
CIST3.DRW

REV A 4/28/94
REV B 5/03/94
REV C 5/09/94
REV D 7/05/94

LSK-12763

Fig. 2
Drawing of the PVC pipe and filling TEE.

Fig. 3
Drawing of detonator assembly.

Test 4 Cable 1 (Interferometer)

Fig. 4.
Typical interferometer record from a single sensor cable on CIST. We show the pre-crush baseline as well as the region where the shock became too weak to further affect the cable. A single loop was used on this sensor.

Derivative of detonation position

Fig. 5
Derivative of detonation position gives a rendition of variations in D , the detonation velocity. The short term variations are most likely cable crush noise.

Fixed Reflection Calibration

Fig. 6

A typical gate calibration record to measure the fixed reflections. At the beginning of the record the probe oscillator was on. When it turned off, the reflections from discontinuities nearest the trailer quit returning first. Finally the reflections from the end of the cable cease. When the probing oscillator was turned back on the nearest reflections returned first. The four phases (1,2,3,4) correspond to the (sine, cosine, -sine, and -cosine) components, respectively, of the signal.

TS1CB1 (Corrected-uncorrected)

Fig. 7
Crush length errors caused by fixed reflections. The figures shows the difference between the corrected and uncorrected values.

CIST Dual RF-14/CORRTEX/RFI

Fig. 8

A comparison between a CORRTEX record and the RF Interferometer (PhaSyR)

Fig. 9
Distributed phase errors in twisted pair cable produced apparent curvature.

TS13CB1

Three Interferometers compared

Fig. 10

A comparison between the LLNL 8 bit interferometer, the LLNL 12 bit interferometer, and the LANL 8 bit "RF CORRTEX"

Fig. 11
Overpressure gage placement for tests 8,9 10 and 11

TEST 12

PENCIL GAGE AIMED DIRECTLY AT FILL END INCIDENT PRESSURE

TEST 13

Fig. 12
Overpressure gage placement for tests 12 and 13

Fig. 13
MERS records from the blast overpressure gages, OP1 and OP2.

Fig. 14
MERS records from the cavity pressure gage with rubber hose and steel tube.

Fig. 15

A comparison between pressure gage 51C at 3 m from the tube end and gage 51D at 70 m from the tube end.

CIST_4

Station 51

Fig. 16

Analog magnetic tape records of three of the cavity pressure gages. Gage 51A and 51B are located about 70 m from the tube end. Gage 51C is located about 3 m from the tube end.

Fig. 17

Raw data record of the PSP pin string. Each of the twelve pins is shown. The three different heights are part of the encoding scheme, as are the gaps between each group of four pins.

CIST 12 PSP pin times

Fig. 18

Pin position as a function of pin closure time. The slope of the straight line fitted through the 12 pin times (6.3232 m/msec) is an example of a measurement of the nitromethane detonation velocity.

APPENDIX A Schematic diagrams of each test

1. Source Characterization. 2 m pipe with CTX and RFI.

Test 1

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	RFI-8	1RFI	FSJ1-50		Short	6.25 MHz
2	CTX-3	1CTX	FSJ1-50		Short	10 microsec
3	CTX-3	2CTX	FSJ1-50		Short	10 microsec
4	RFK-1	*	FSJ4-50	4.8 m	Short	10 MHz
5	RFK-2	*	FSJ1-50	4.4 m	Short	10 MHz
6	CTX-3	*	FSJ1-50	4.42 m	Short	12 microsec

Dashed areas denote recording by LANL

2. Source characterization. 8 m pipe

Test 2

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	CTX-3	1CTX	RG-174		Short	10 microsec
2	RFI-8	1RFI	FSJ1-50		Short	6.25 MHz
3	RFI-8	2RFI	RG-174		Short	6.25 MHz
4	RFK-1	*	FSJ4-50	9.61 m	Short	10 MHz
5	RFK-2	*	FSJ4-50	2.4 m	Short	10 MHz
6	CTX-3	*	FSJ1-50	8.92 m	Short	12 microsec

3. CORRTX/RFI Comparison

Test 3

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	CTX-3	1CTX	FSJ1-50		Short	10 microsec
2	RFI-8	1RFI	FSJ1-50		Short	6.25 MHz
3	RFI-8	2RF1	Dual RF-14		Short	6.25 MHz
		2CTX	Dual RF-14		Short	10 microsec
4	CTX-3	3CTX #	Twisted Pr		Short	10 microsec
Cavity Pressure						
5	RFK-1	*	RF-174	2	Short	10 MHz
6	RFK-2	*	RF-174	2	Short	20 MHz
7	CTX-3	*	RF-174	2	Short	12 microsec

Cable left in jacket...used one pair of four.

4. Helical CTX/RFI Calibration

Test 4

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	RFI-12	1RFI	FSJ1-50		Short	8.33 MHz
2	RFI-12	2RFI	RG-174		Short	8.33 MHz
3	CTX-3	1CTX	FSJ1-50		Short	12 microsec
4	CTX-3	2CTX	FSJ1-50		Short	12 microsec
Cavity Pressure						
5	RFK-1	*	FSJ1-50	0	Short	10 MHz
6	RFK-2	*	FSJ1-50	0	Short	20 MHz

5. PSP Test

Test 5

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./Sampling
1	RFI-12	1RFI	FSJ1-50		Short	8.33 MHz
2	DSP		PSP			50 Ms/sec
3	RFI-12	2RFI	Twisted Pr		Short	8.333 MHz
4	CTX-3	1CTX	Twisted Pr		Short	12 microsec
Cavity Pressure						
5	RFK-1	*	FSJ1-50	11.51	Short	10 MHz
6	RFK-2	*	FSJ1-50	2.88	Short	10 MHz
7	CTX-3	*	FSJ1-50	2		12 microsec

6. Side Incidence Test

Test 6

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	CTX-3	1CTX	FSJ1-50		Short	12 microsec
2	RFI-12	1RFI	FSJ1-50		Short	6.25 MHz
3	RFI-12	2RFI	FSJ4-50		Short	8.333 MHz
4	CTX-3	2CTX	FSJ1-50		Short	12 microsec
Cavity Pressure						
5	CTX-3	*	RF-174	2		12 microsec
6	RFK-1	*	RF-174	2	Short	10 MHz
7	RFK-2	*	RF-174	2	Short	10 MHz

7. Two loop Test

Test 7

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	CTX-3	1CTX	FSJ1-50		Short	12 microsec
2	RFI-12	1RFI	FSJ1-50		Short	8.333 MHz
3	RFI-12	2RFI	Dual RF-14		Short	8.333 MHz
	CTX-3	2CTX			Short	12 microsec
4	CTX-3	3CTX	Twisted Pr		Short	12 microsec
Cavity Pressure						
5	RFK-1	*	FSJ1-50	2.88	Short	20 MHz
6	RFK-2	*	FSJ1-50	5.75	Short	10 MHz
7	CTX-3	*	FSJ1-50	2	Short	12 Microsec

8. Helical CTX/RFI Calibration

Test 8

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./Sampling
1	RFI-8	1RFI	FSJ1-50		Short	8.333 MHz
2	RFI-12	2RFI	FSJ4-50		Short	8.333 MHz
3	CTX-3	1CTX	FSJ1-50		Short	12 microsec
4	CTX-3	2CTX	FSJ4-50		Short	12 microsec
Cavity Pressure						
5	RFK-1	*	FSJ1-50	0	Short	10 MHz
6	RFK-2	*	FSJ1-50	0	Short	20 MHz

9. LANL

Test 9

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	CTX-3	1CTX	FSJ1-50		Short	12 microsec
2			FSJ1-50			
3			FSJ1-50			
4			FSJ1-50			
5	Dummy cable for mechanical stability only.					
6	CTX-3	2CTX	RG-174		Short	12 microsec
7	CTX-3	3CTX	HJ-4		Short	12 microsec

10. Helical CTX/RFI calibration

Test 10

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./Sampling
1	CTX-3	1CTX	RF174		Short	12 microsec
2	CTX-3	2CTX	RF174		Short	12 microsec
3	RFI-12	1RFI	FSJ1-50		Short	8.333 MHz
4	RFI-12	2RFI	FSJ4-50		Short	8.333 MHz
Cavity Pressure						
5	RFK-1	*	FSJ1-50	0	Short	10 MHz
6	RFK-2	*	FSJ1-50	0	Short	20 MHz

11. Crush Threshold Test

Test 11

Cable #	Unit	Channel Designator	Type	Crush Length (m)	Term.	Freq./ Sampling
1	CTX-3		FSJ1-50		Short	12 microsec
2	CTX-3		FSJ1-50		Short	12 microsec
3	CTX-3	1CTX	FSJ1-50		Short	12 microsec
4	CTX-3	2CTX	FSJ1-50		Short	12 microsec
5	CTX-3	3CTX	FSJ4-50		Short	12 microsec
6	RFI-12	1RFI	Twisted Pr		Short	8.333 MHz
7	RFI-12	2RFI	RF-214		Short	8.333 MHz
8	CTX-3	4CTX	RF-174		Short	12 microsec

12. Additional test

Test 12

Cable #	Unit	Channel Designator	Type	Notes	Freq./ Sampling
1	CTX-3	1CTX	FSJ1-50	Center of pipe	12 microsec
2	PSP		PSP	Tape to pipe starting at 3m	
3	RFI-12		RG-58	2m foldback, exit pipe 7m	8.333MhZ
4	CTX-3	2CTX	Ribbon	2m foldback, exit pipe 7m	12 microsec
5	RFI-12		Ribbon	Run cable near detonator.	12 microsec
Cavity Pressure					
6	CTX-3		Microdot250	2m foldback, exit pipe 7m	
7	RFK-1		Microdot250	2m foldback	8.333MhZ
8	CTX-3		RG-58	2m foldback, exit pipe 7m	12 microsec

13. One more additional test

Test 13

Cable #	Unit	Channel Designator	Type	Notes	Freq./ Sampling
1	RFK-1		FSJ1-50	2m foldback and up standpip	
2	RFI-12		Microdot250	2m foldback, exit pipe 7m	8.333 MHz
3	CTX-3		Microdot250	Run cable near detonator	12 microsec
4	CTX-3		RG402	2m foldback, exit pipe 7m	12 microsec
5	RFI-12		RG402	2m foldback	8.333 MHz
Cavity pressure					
6	RFK-2		Ribbon	2m foldback	
7	CTX-3		Ribbon	2m foldback, exit pipe 7m	12 microsec

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