TECHNICAL NOTE TN-SM-84-14

(NASA-CR-171028) PRETEST PLAN FOR A QUARTER SCALE AFT SEGMENT OF THE SRB FILAMENT WOUND CASE IN THE NSWC HYDROBALLISTICS FACILITY (Chrysler Corp.) 29 p HC A03/MF A01 CSCL 22B G3/16

N84-24699

Unclas 19263

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MARCH 1984

CONTRACT: NAS8-35017

SHUTTLE TECHNOLOGY

HUNTSVILLE ELECTRONICS DIVISION CHRYSLER CORPORATION

MICHOUD ENGINEERING OFFICE

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PRETEST PLAN FOR A QUARTER SCALE AFT SEGMENT OF THE SRB FILAMENT WOUND CASE IN THE NSWC HYDROBALLISTICS FACILITY

TEST #84-1

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SECTION 1.0 - INTRODUCTION

NASA's Space Shuttle vehicle employs reusable rocket boosters. Recovery is achieved by utilizing a parachute deceleration system with terminal impact in the ocean down range of the launch site. The boosters impact nozzle first to take advantage of the high drag characteristics of the nozzle/skirt/aft bulkhead projected area to minimize penetration depth, while utilizing the hydropneumatic piston damping effect of the motor case chamber to retard rebound and slap-down. Nominal impact conditions at initial water impact occur over a range of vertical velocities, with horizontal velocities of 0 to 45 fps and initial impact attitudes of $\theta = 0$ to $\pm 10^{\circ}$. The boosters experience high local pressures and deceleration loads which must be defined as structural design attrition analysis and operational criteria.

In support of pre-flight design loads definition, the Systems Dynamic Laboratory of MSFC has conducted preliminary water impact scale model test programs at the Naval Surface Weapons Center's (NSWC) Hydroballistics Facility at White Oak, Maryland. These tests were designed to provide accelerations, pressures, and forces for initial impact of the boosters. Preliminary loads of previous study configurations were defined by Chrysler in Contracts NAS8-28088, NAS8-28988, NAS8-33879, and NAS8-35017 using similar test methods.

The objective of this test on a quarter scale FWC segment of the SRB is:

a. Evaluate dynamic response characteristics of a FWC composite type structure when subjected to a water impact cavity collapse impulsive loading.

b. Obtain dynamic structural response measurements for use as a data base for FWC flight evaluation purposes.

c. Determine the cavity collapse dynamic pressure loading environment.

d. Measure overall scale model body responses to develop a balanced loads criteria.

e. Assess the atmospheric pressure scaling effect on the applied pressures, cavity shape, and cavity closure dynamics.

This document presents the test plan for water impact testing on the quarter scale FWC segment at test conditions to simulate full-scale initial impact at vertical velocities from 65 to 85 ft/sec, zero horizontal velocity, and angles of 0, 5, and 10 degrees. Atmospheric scaling will be used.

SECTION 2.0 - MODEL DESCRIPTION

The test model used for this testprogram represents a quarter scale model of the aft segment area of the SRB FWC, as shown in Figure 1. The test article is comprised of five major structural elements, each of which is attached to their adjacent elements by mechanical fasteners. These five major elements are the (1) aft skirt, (2) inner measurement cylinder, (3) FWC segment, (4) forward cylinder, and (5) forward cylinder extension. These parts are constructed of steel and aluminum except for the FWC segment which is a quarter scale carbon filament wound segment. The aft skirt is designed to simulate, in the best practical means, the scaled radial stiffness and joint bending stiffness at the FWC segment/aft skirt interface. The aft skirt is also designed to be readily attached/detached from the inner measurement cylinder. No attempt is made to duplicate the full-scale model since the model aft skirt is only meant to represent an interface stiffness and generate a cavity. Ballast weights will be attached inside the aft skirt to bring the total test article weight to 2,000 lb. $\pm$100 lbs. The inner measurement cylinder is used as a rigid mounting base for the relative deflection measurements and rigid body accelera-ons. This cylinder is constructed so its beam bending and shell ial modal frequencies are significantly higher than the corresponding requencies of the FWC model segment. As a design goal, the lowest modal frequency of the inner cylinder shall be 300 hz or higher. The FWC segment of this test article is the quarter scale segment model used in MSFC modal testing. This segment does not have scaled joints or case stiffner rings as the full-scale aft segment does. It is, however, constructed of the same materials in the same fashion as the full-scale FWC. The forward extention is simply a two-foot-long removable cylindrical structure to be used only if the keel side penetration depth, for a given impact condition, is above the regular forward cylinder.

In addition to the basic requirements discussed above, the test article includes appropriate attach points for handling during assembly, launcher installation, instrumentation cable attach, deceleration cable system interface, and safety cable attach. After assembly, the test article will be weighed and the pitch moment of inertia measured. Although pitch inertia is not to be scaled, its measured value is needed to adjust the dynamic rigid body response when extrapolating to full scale.

The test article will have the paint pattern shown in Figure 2 to assist in post test motion picture photographic analysis. In addition, other open surfaces will be painted to prevent corrosion. Interface areas, such as joints, will have grease applied to ease in assembly/ disassembly and to inhibit corrosion.

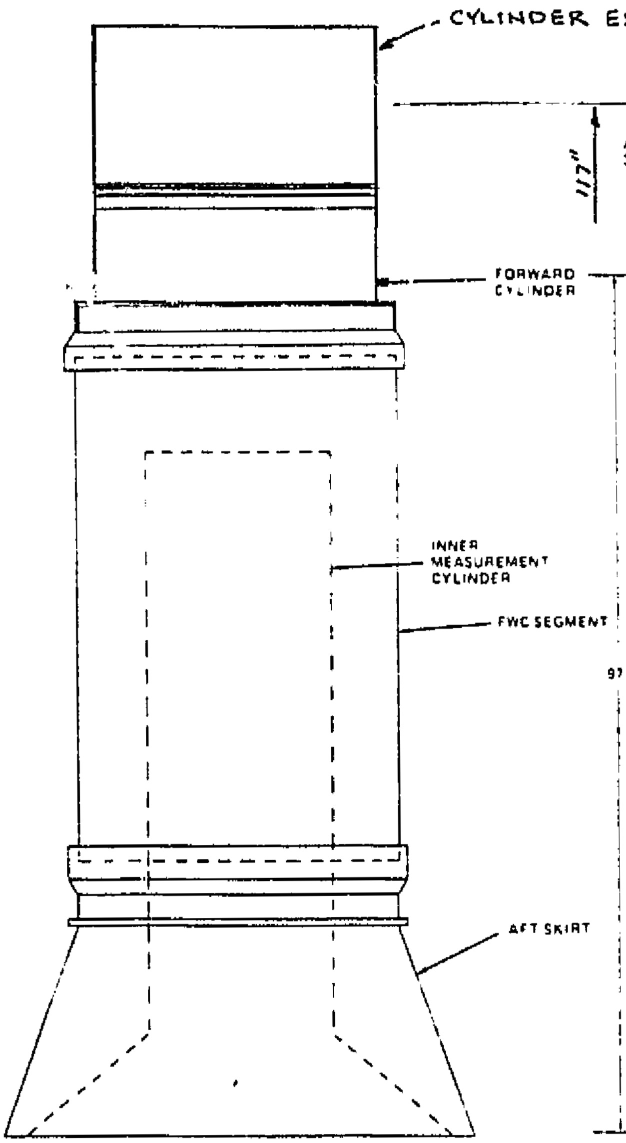

FIGURE 1 WATER IMPACT TEST ARTICLE

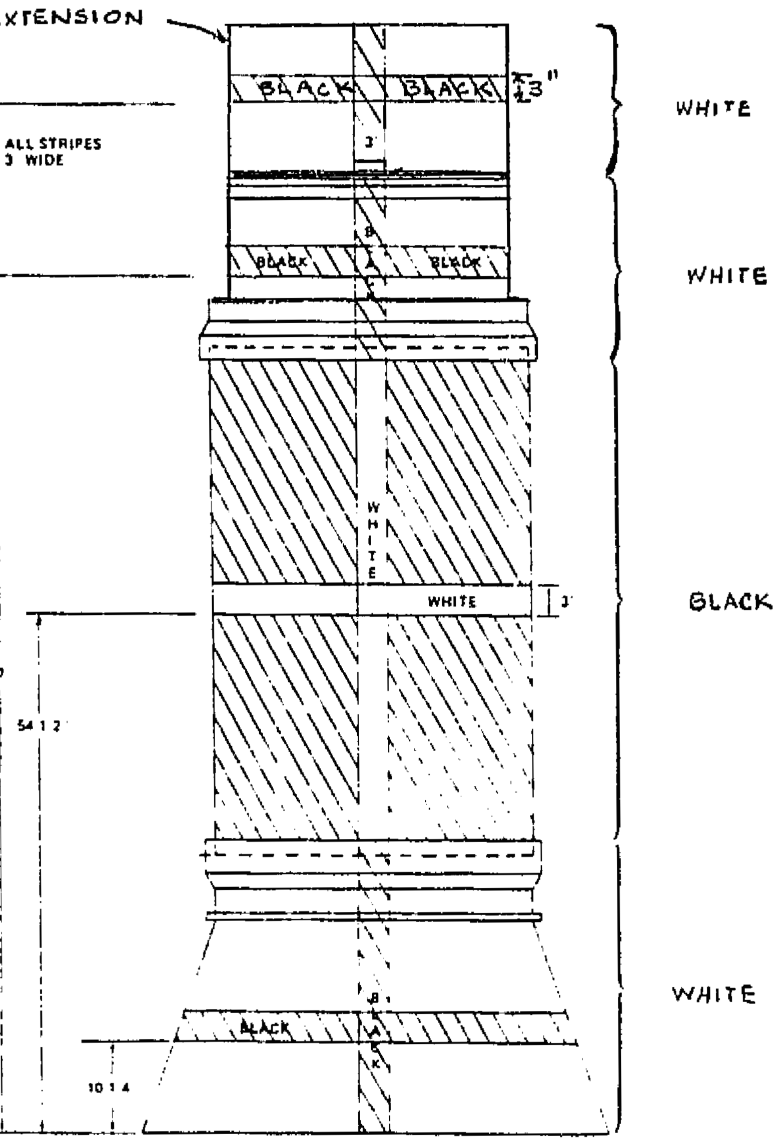

FIGURE 2 PAINT PATTERN

SECTION 3.0 - INSTRUMENTATION

The model instrumentation will consist of deflection, pressure, acceleration, and strain measurements. Table 1 contains the instrumentation list and Figures 3-6 present the measurement locations. The test article will be instrumented with 18 deflection gages, 22 pressure transducers, 16 accelerometers, and 32 uniaxial strain gages for a total of 92 measurements.

The pressure transducers will be hermetically sealed, electrically isolated from the model case, and will be chosen for high resonant frequency and rapid response to dynamic environments.

Only 78 data channels, however, will be recorded on any given run. Time code shall be recorded on every fourteenth tape recorder channel. Definition of specific measurements to be recorded will be coordinated with test and analysis personnel and the MSFC technical representative prior to each test.

The data acquisition and recording system shall be capable of recording signals with 0 to 10 Khz frequency content. The measurements shall be recorded direct FM on magnetic tape with a carrier frequency of 108 Khz at a recording speed of 30 ips. The data are, in general, to be digitized at 10,000 samples/sec.

Photographic coverage for this test will be provided by two high speed 16mm data cameras, and one 16mm documentary camera. The d ta cameras will be set up in and perpendicular to the model pitch and yaw planes.

They will be sighted so that the lens centerline will be at the water surface to permit split water line viewing above and below water with each camera. Camera speeds will be approximately 250 fps, with 1/650 sec. exposure time.

The documentary camera will be located in front of and above the model impact point and run at a camera speed of 24 fps.

Tank lighting will consist of 7 banks of 12 bulbs each below the water and 2 banks of 12 bulbs each and 4 light bars with 2 bulbs each above the water line. All bulbs will be 650 watt. A blue vinyl back drop 25 ft. wide by 20 ft. long will be suspended from the bridge to improve tank lighting. The west wall of the tank is presently covered with white vinyl.

Still documentary color photographs will be made of all model configurations, instrumentation and recording equipment facilities.

Meas. No.	Measurement Type	Range	Location	Remarks
D1			STA 45.0 (TDC) 0^{0}	
D2	LINEAR	$\pm 2''$	30^{0}	
D3	VARIABLE		60^{0}	
D4	DIFFERENTIAL		90^{0}	
D5	TRANSFORMER		180^{0}	
D6	(LVDT)		270^{0}	
D7	SCHAEVITZ		300^{0}	
D8	ENGINEERING		STA 45.0 330^{0}	
D9	MODEL 2002XSD		STA 55.5 (TDC) 0^{0}	
D10			30^{0}	
D11			60^{0}	
D12			90^{0}	
D13			180^{0}	
D14			270^{0}	
D15			300^{0}	
D16			STA 55.0 330^{0}	
D17			STA 69.5 (TDC) 0^{0}	
D18			STA 69.5 180^{0}	

TABLE I INSTRUMENTATION

Meas. No.	Measurement Type	Range	Location	Remarks
P1	PCB	2000PSIG	STA 32.0 (TDC) 0^0	
P2	PIEZOTRONICS		STA 32.0 180^0	
P3	HIGH FREQ		STA 37.5 (TDC) 0^0	
P4	MODEL		STA 37.5 180^0	
P5	H113 A22		STA 42.5 (TDC) 0^0	
P6	PRESSURE		STA 42.5 180^0	
P7	TRANSDUCERS		STA 45.0 (TDC) 0^0	
P8			10^0	
P9			30^0	
P10			90^0	
P11			180^0	
P12			270^0	
P13			STA 45.0 340^0	
P14			STA 47.5 (TDC) 0^0	
P15			STA 47.5 180^0	

TABLE I INSTRUMENTATION

Meas. No.	Measurement Type	Range	Location	Remarks
P16	PCB	2000PSIG	STA 55.0 (TDC) 0^{0}	
P17	PIEZOTRONICS		10^{0}	
P18	HIGH FREQ		30^{0}	
P19	MODEL		90^{0}	
P20	H113A22		180^{0}	
P21			270^{0}	
P22			STA 55.0 340^{0}	

TABLE I INSTRUMENTATION

Meas. No.	Measurement Type	Range	Location	Remarks
AX1	PCB	500 G's	TOP INNER TUBE STA 68.5 (TDC) 0^{o}	(AXIAL)
AZ1	MODEL H302-A04		TOP INNER TUBE STA 68.5 (TDC) 0^{o}	(PITCH)
AZ2	QUARTZ		AT C.G. INNER TUBE STA (TDC) 0^{o}	(PITCH)
AY1	ACCELEROMETER		C.G. INNER TUBE STA 90^{o}	(YAW)
A1			STA 45.0 (TDC) 0^{o}	
A2			20^{o}	
A3			90^{o}	
A4			180^{o}	
A5			330^{o}	
A6			350^{o}	
A7			STA 55.0 (TDC) 0^{o}	
A8			20^{o}	
A9			90^{o}	
A10			180^{o}	
A11			330^{o}	
A12			350^{o}	

TABLE I INSTRUMENTATION

Meas. No.	Measurement Type	Range	Location	Remarks
G1	DENTRONICS		STA 45.0 (TDC) 0^o OUTER AXIAL	
G2	STRAIN		(TDC) 0^o OUTER TANG	
G3	GAGE		(TDC) 0^o INNER AXIAL	
G4	TYPE		(TDC) 0^o INNER TANK	
G5	AP2316N		90^o OUTER AXIAL	
G6	C6ETS		90^o OUTER TANG	
G7	10 MILS		90^o INNER AXIAL	
G8	KAPTON		90^o INNER TANG	
G9			180^o OUTER AXIAL	
G10			180^o OUTER TANG	
G11			180^o INNER AXIAL	
G12			180^o INNER TANG	
G13			270^o OUTER AXIAL	
G14			270^o OUTER TANG	
G15			270^o INNER AXIAL	
G16			STA 45.0 270^o INNER TANG	

TABLE I INSTRUMENTATION

Meas. No.	Measurement Type	Range	Location	Remarks
G17			STA 55.5 (TDC) 0^{o} OUTER AXIAL	
G18	DETRONICS		(TDC) 0^{o} OUTER TANG	
G19	STRAIN		(TDC) 0^{o} INNER AXIAL	
G20	GAGE		(TDC) 0^{o} INNER TANG	
G21	TYPE		90^{o} OUTER AXIAL	
G22	AP2316N		90^{o} OUTER TANG	
G23	C6 ETS		90^{o} INNER TANG	
G24	10 MILS		90^{o} INNER TANG	
G25	KAPTON		180^{o} OUTER AXIAL	
G26			180^{o} OUTER TANG	
G27			180^{o} INNER AXIAL	
G28			180^{o} INNER TANG	
G29			270^{o} OUTER AXIAL	
G30			270^{o} OUTER TANG	
G31			270^{o} INNER AXIAL	
G32			STA 55.5 270^{o} INNER TANG	

TABLE I INSTRUMENTATION

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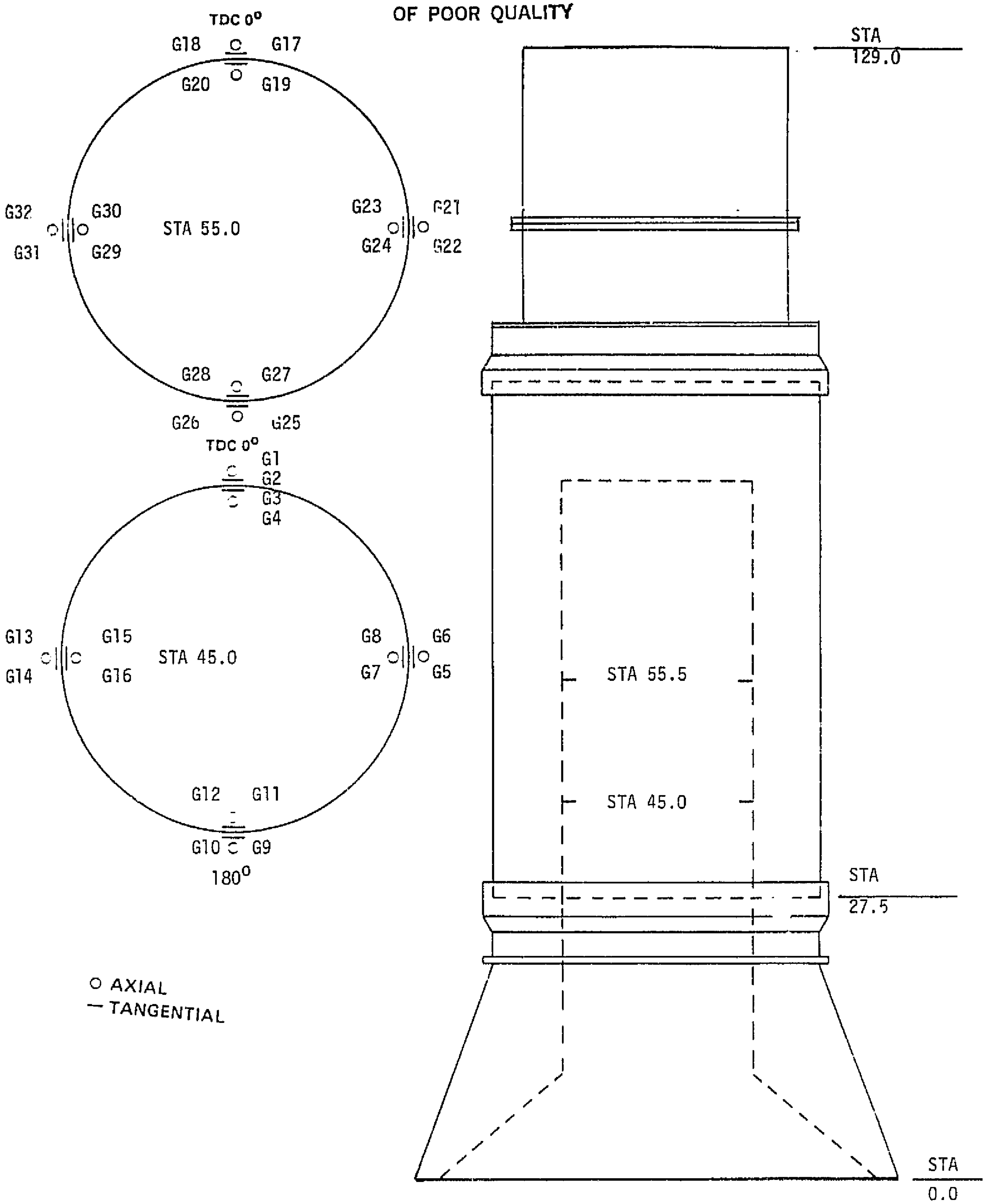

FIGURE 3. STRAIN GAGE LOCATIONS

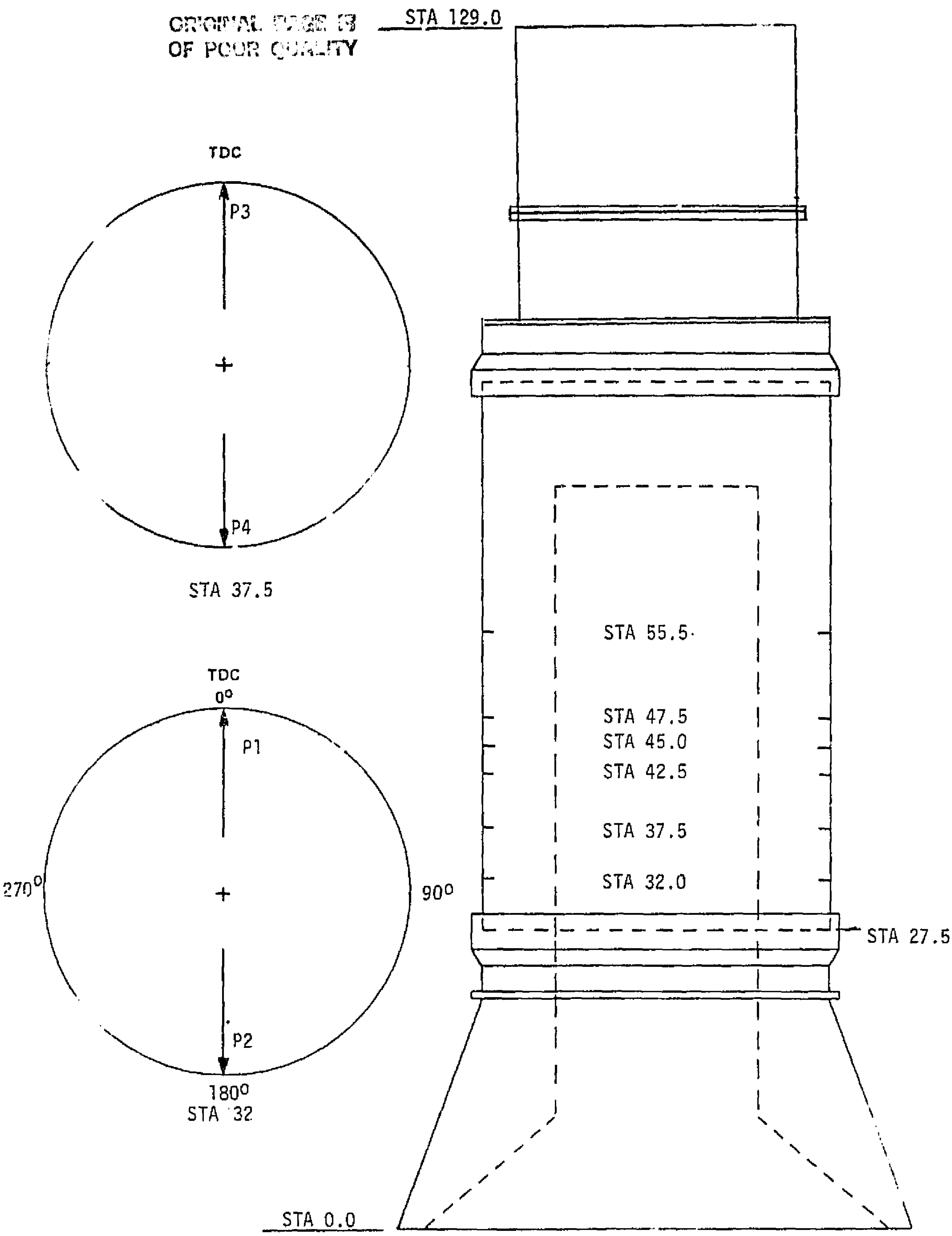

FIGURE 4a. PRESSURE GAGE LOCATIONS

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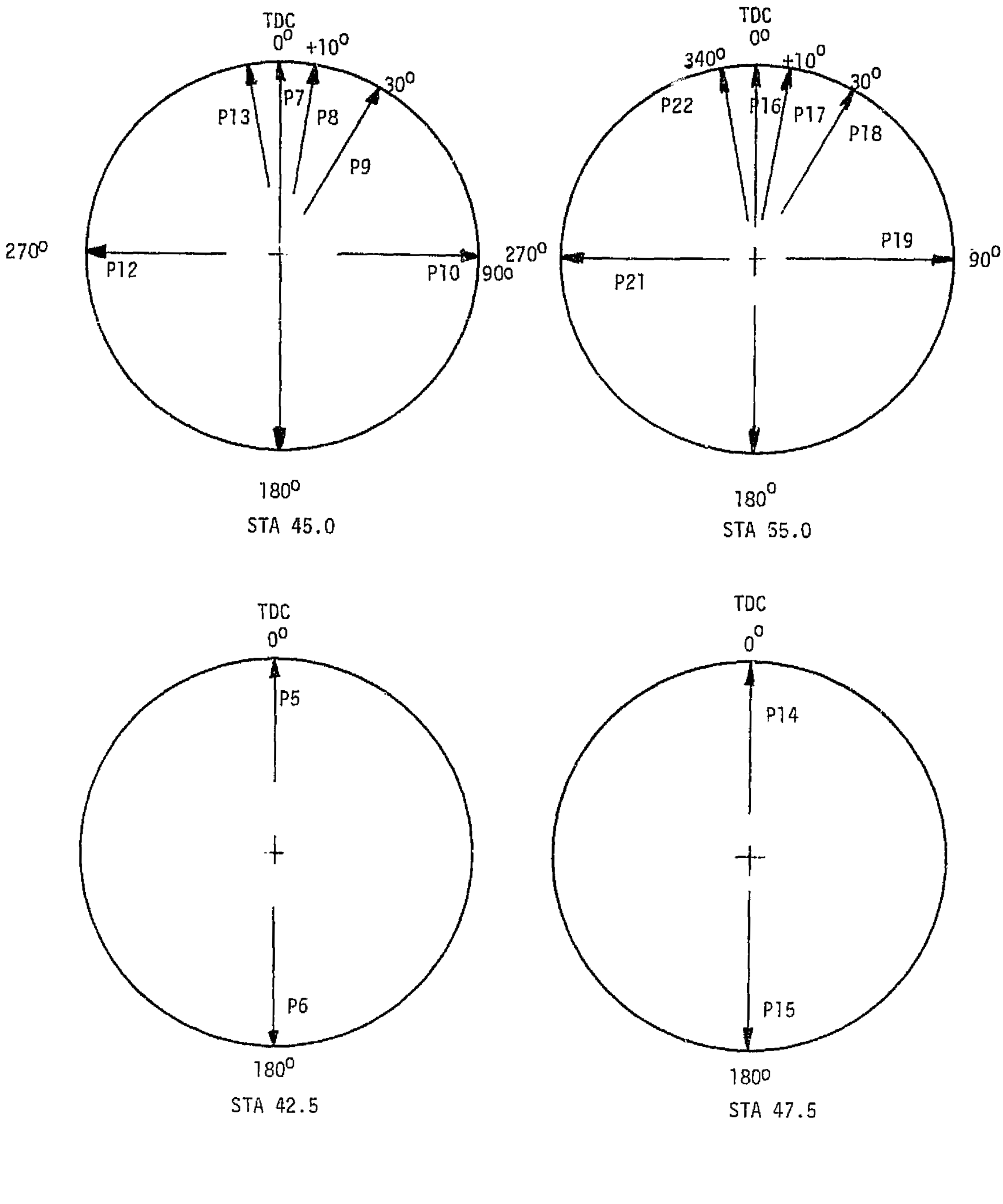

FIGURE 4b. PRESSURE GAGE LOCATIONS

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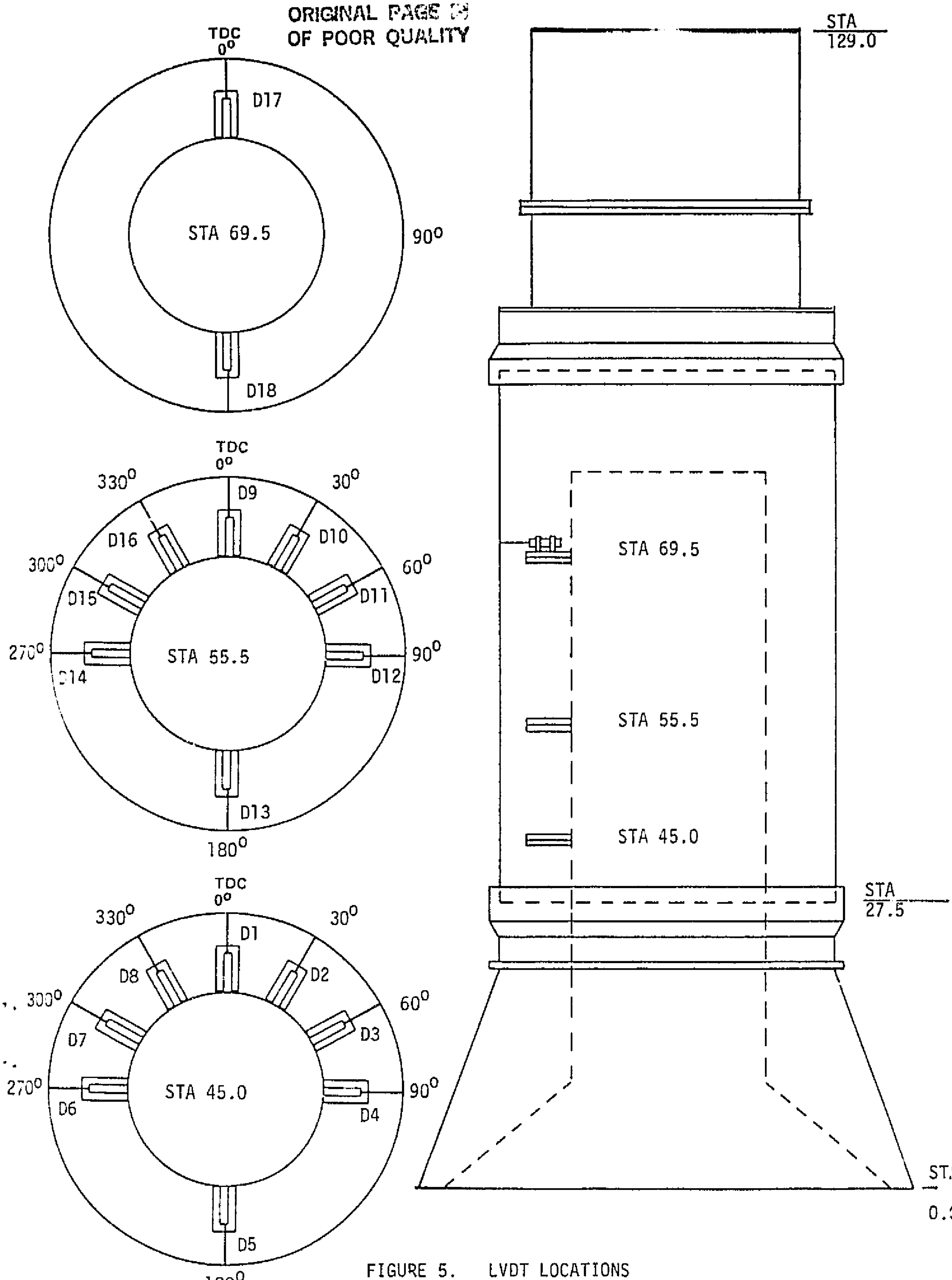

FIGURE 5. LVDT LOCATIONS

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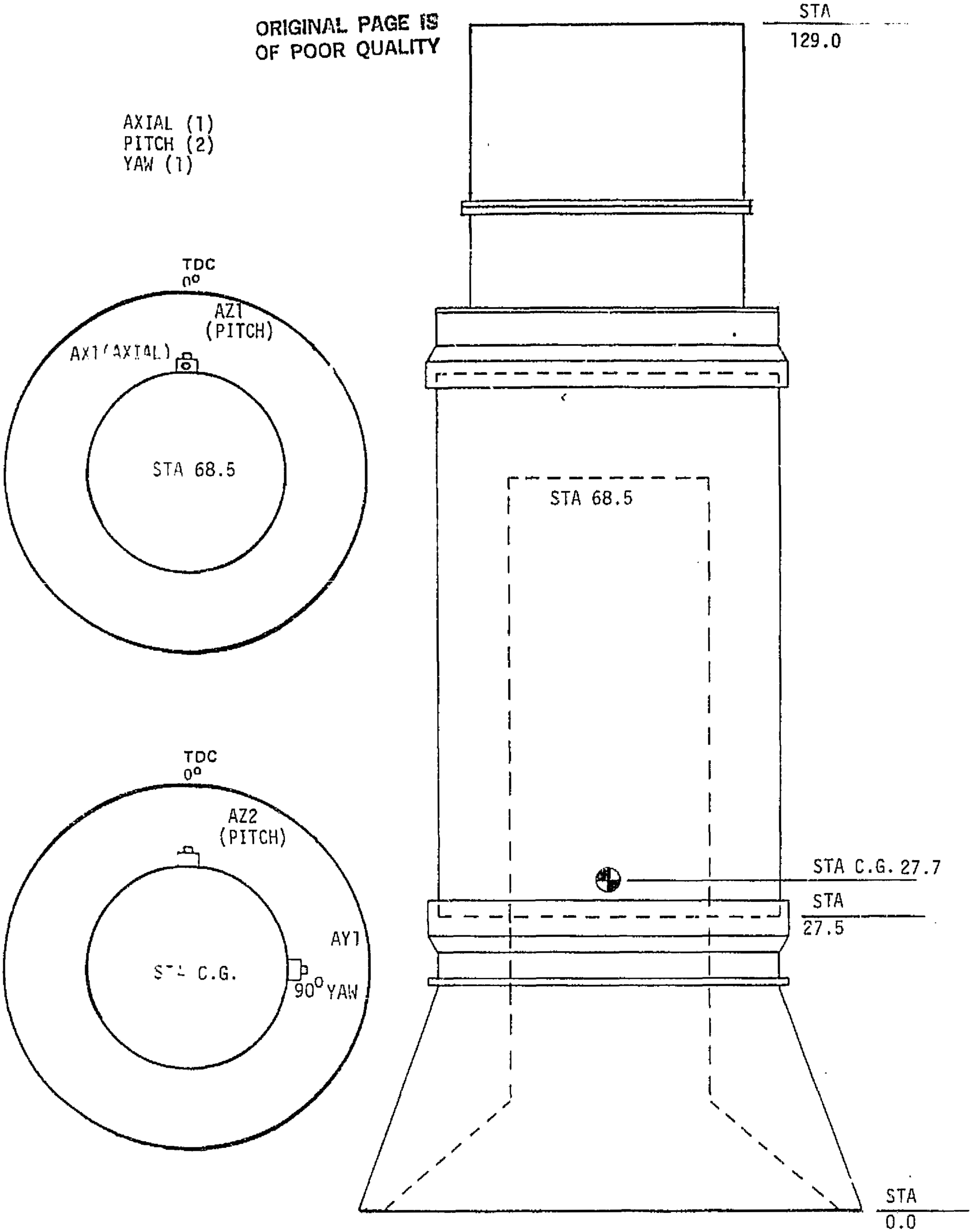

IGURE 6a. ACCELEROMETER LOCATIONS

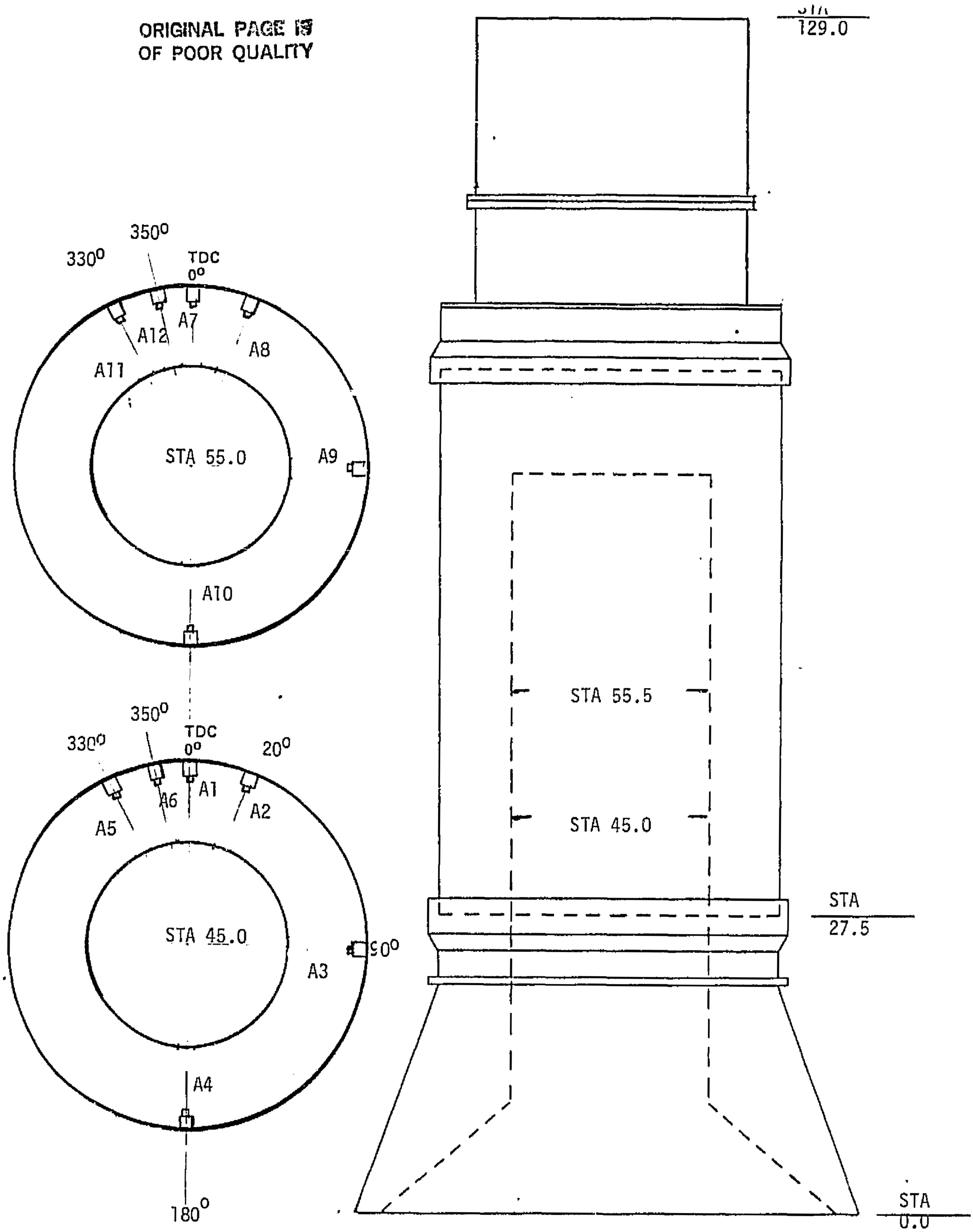

FIGURE 6b. ACCELEROMETER LOCATIONS

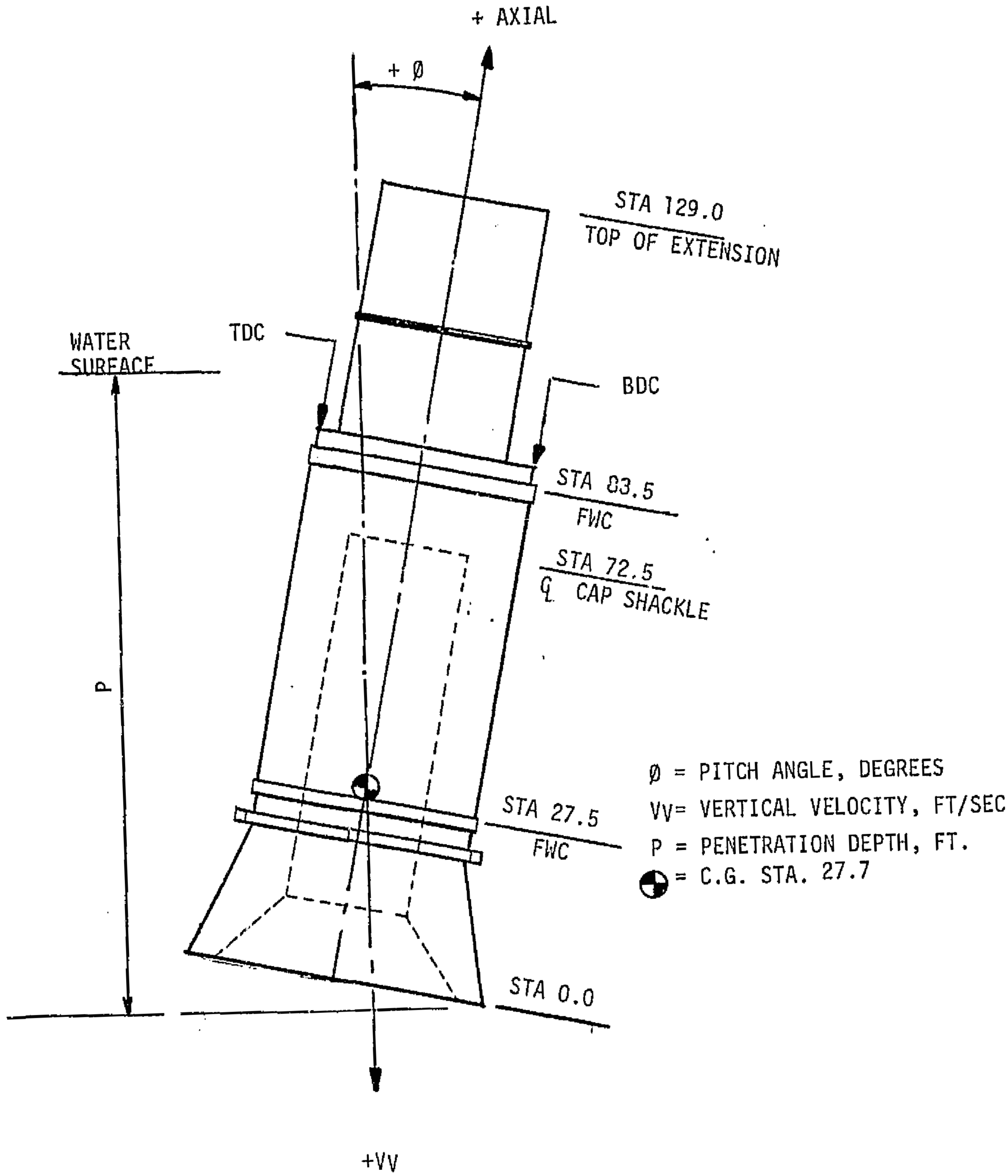

FIGURE 7. CO-ORDINATE SYSTEM

SECTION 4.0 - TEST PROCEDURE

The test program will be conducted in the NSWC Hydroballistics Facility described in Section 5.0.

Froude scaled model initial impact test conditions shall be used to simulate full-scale initial impact conditions of vertical velocities from 65 to 85 ft/sec., zero horizontal velocity, and angles of 0, 5 and 10 degrees. Figure 7 shows the coordinate system for the model. Atmospheric scaling will be used. Table II is the proposed test matrix. Additions or deletions to this test matrix will be at the discretion of the NASA/MSFC technical representative.

The recording sequence for each drop will be approximately three (3) seconds in duration and will include a simultaneous calibration step of approximately one (1) second on each channel.

TABLE II - PROPOSED SRB WATER IMPACT DROP TEST MATRIX

CONFIGURATION	VERTICAL VELOCITIES (FPS)		TANK PRESSURE (PSIA)	ROLL ANGLE DEGREES Ø	TEST NUMBERS IMPACT ANGLES DEGREES θ				
	FULL SCALE	MODEL SCALE			-10	-5	0	5	10
I	65	32.5	14.7	0			1		2
I	65	32.5	3.7	0			5	4	3
I	75	37.5	3.7	0			6	7	8
I	85	42.5	3.7	0			11	10	9
I	65	32.5	TBD	0			12	-	13
TBD	65	32.5	3.7	0			TBD		
TBD	75	37.5	3.7	0			TBD		
TBD	85	42.5	3.7	0			TBD		

SECTION 5.0 - TEST FACILITY

This test will be conducted in the Hydroballistics Tank at the U.S. Naval Surface Weapons Center, White Oak, Maryland. This tank is 35 feet wide, 100 feet long and 75 feet deep with a water depth variable from zero to 65 feet. To preserve water clarity the tank is lined with stainless steel and the water is continuously filtered. A two foot thick reinforced concrete honeycomb structure surrounds the tank and is designed to permit reduction of air pressure above the water for model scaling. Steam ejectors located on the building roof are used to evacuate the tank for pressure scaled tests.

Depending upon water level, access to the tank is obtained either through a door in the bottom of the tank, two personnel hatches in the ceiling, or by removing one of the nine 3-foot diameter gun ports located in the north wall and ceiling. Work inside the tank is performed from either a raft, a catwalk, or a movable bridge 6.5 feet high by 10 feet wide which spans the 35 foot width of the tank at the 61 foot elevation. For photographic or visual observations 16 inch diameter portholes are located 11 feet on center in the tank floor, walls, and ceiling.

SECTION 6.0 - DATA REDUCTION

The first phase of data reduction will be conducted on site at the test facility. Oscillograph plots of all measurements will be made and time correlated. Quick look values will be read and recorded on data log sheets for use in verifying test quality, full scale simulations, and preliminary analyses.

Copies of each data tape will be made and shipped to the MSFC computation laboratory to be demodulated, filtered with 5000 Hz low pass filters, digitized at 10,000 samples per second and converted to engineering units. Digital tapes with data in engineering units will be forwarded to the Slidell Computer Center for further processing and plotting.

All photographic film will be processed at NSWC and analyzed at the Michoud Assembly Facility.