

# MEMORANDO TÉCNICO Nº NaN/ APR-E / 2019



DE: APR-E	PARA: APR-E	DATA: 03/07/2019
PROJETO: Motor Foguete L75	PROTÓTIPO:	SISTEMA/SUBSISTEMA/SEGMENTO: Combustion System
ASSUNTO: Abridged report for Subscale Thrust Chamber hot firing test		
SOLICITANTE: Leonardo Bartholomeu do Nascimento — Maj Eng		

## Report of SSTC Hot Test #37

### 1 Introduction

The purpose of this technical memorandum is to provide a quick report for documenting a single firing test during the Subscale Capacitive Thrust Chamber Test Campaign. The aforementioned firing occurred in July, 03, 2019, at 15:49. For this firing, the test subject and test bench settings are displayed in tables 1 and 2.

The test subject setup diagram is presented in figure 1 as for the 20kN test bench schematics is presented in 2

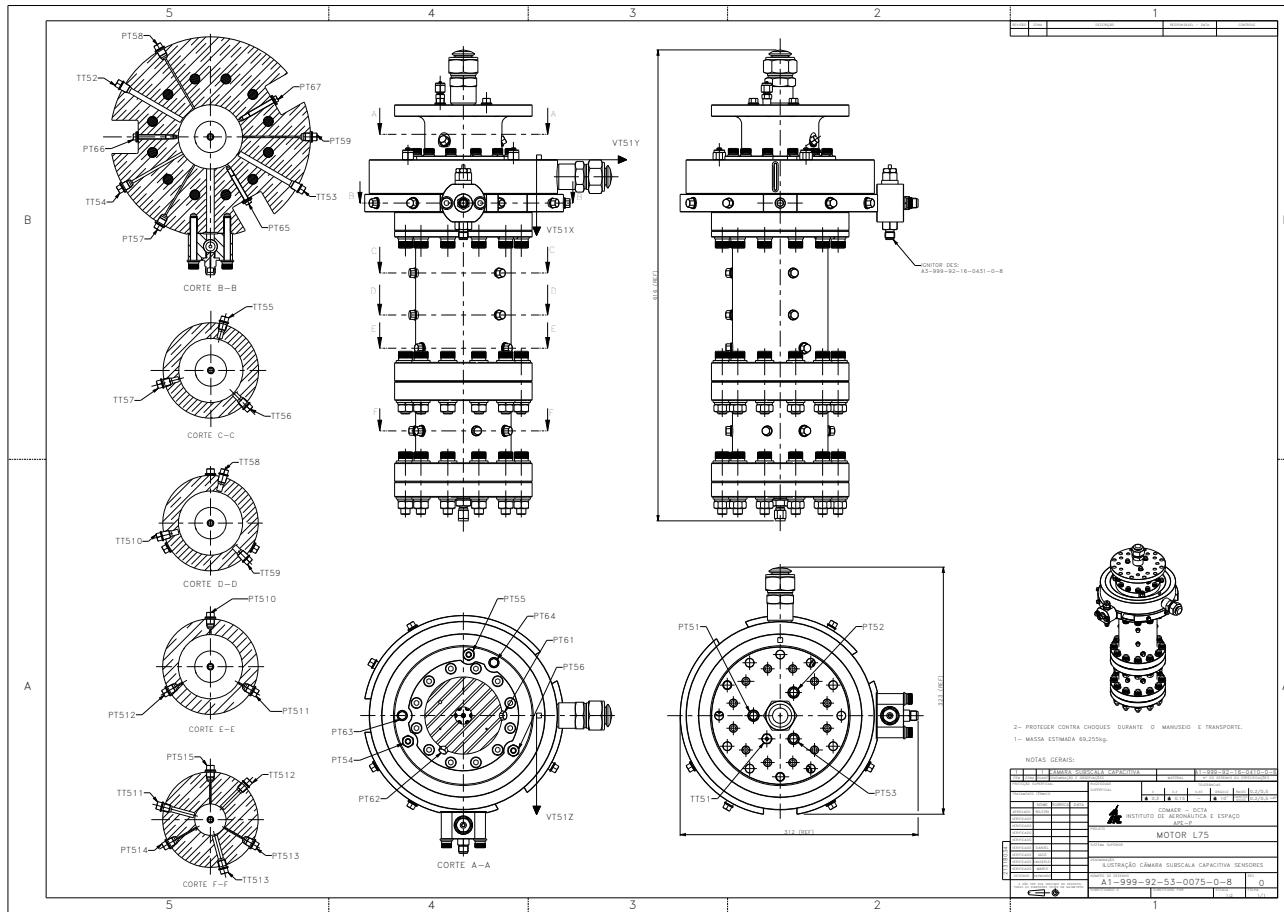


Figure 1: Test subject setup diagram.

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OBSERVAÇÕES: <ul style="list-style-type: none"> <li>- Será emitido relatório? <input checked="" type="checkbox"/> SIM <input type="checkbox"/> NÃO</li> <li>- Haverá revisão de conteúdo? <input type="checkbox"/> SIM <input checked="" type="checkbox"/> NÃO</li> <li>- Substitui MMOTEC Nº</li> <li>- Complementa MMOTEC Nº</li> </ul>	ANEXOS: <ul style="list-style-type: none"> <li>TABELAS <input type="checkbox"/></li> <li>FIGURAS <input type="checkbox"/></li> </ul>	PÁGINA 1 / 8

## 2 Test results

### 2.1 Test parameters

Test parameters are displayed in table 3.

The ignition and shutdown sequences are represented in table 4. VP25 refers to the ethanol main valve, while VP16 refers to LOx main valve.

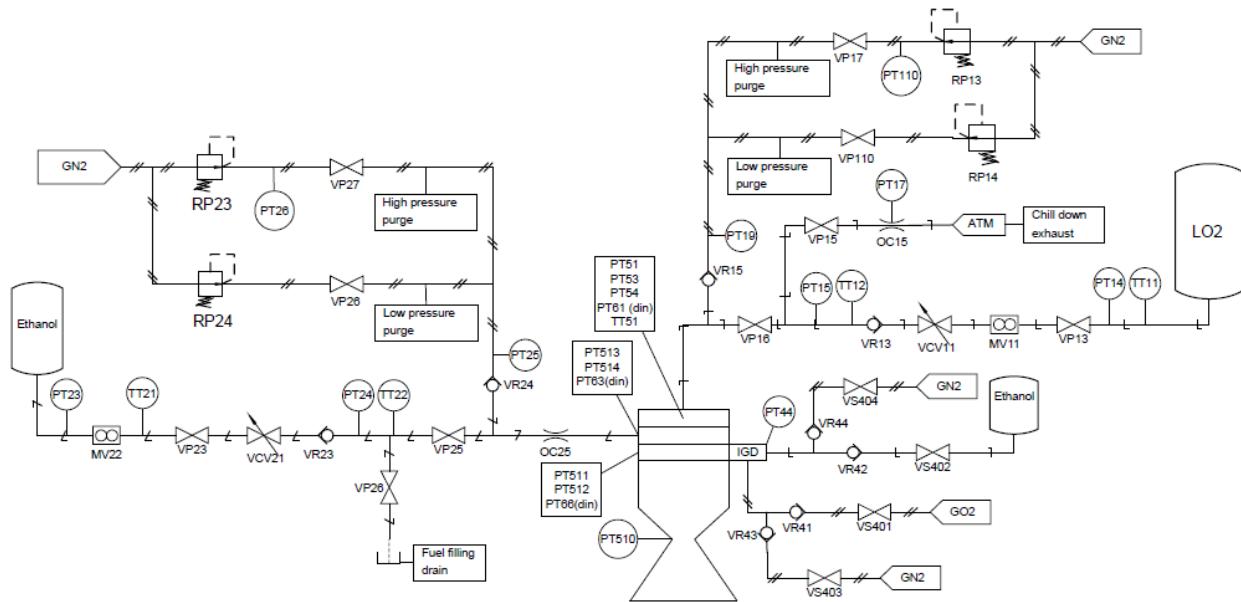


Figure 2: Test bench setup diagram.

Table 1: Test subject settings and general info. Please refer to Fig. 1 for clarification.

Description	Value
Mixing Head Number	MH#2
Hardware Cylindrical Type	Capacitive
Hardware Throat Type	Capacitive
$\mu_F$ MH Fuel Side	4,72e-005
$\mu_F$ MH Oxidizer Side	7,85e-005
Throat diameter [mm]	71,19
Test time [s]	3,4

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Table 2: Test bench settings for valves and regulators.

Component	Description	Value	Unit
RP11	Main LOx tank pressure	38,7	bar
RP21	Main ethanol tank pressure	54,1	bar
RP41	GOx igniter tank pressure	58	bar
RP42	Ethanol igniter tank pressure	18	bar
RP13	High pressure LOx purging pressure	100	bar
RP14	Low pressure LOx purging pressure	8	bar
RP23	High pressure ethanol purging pressure	100	bar
RP24	Low pressure ethanol purging pressure	8	bar
VCV11	LOx line proportional valve	100	%
VCV21	Ethanol line proportional valve	100	%

Table 3: Test results.

Name	Expected value	Measured value	Error (%)	Unit
Chamber pressure	24,1	23,6725	-1,7739	bar
LOx inlet pressure	32,8024	32,5839	-0,66599	bar
LOx inlet temperature	100	110,8272	10,8272	K
LOx density	1096,9361	1104,8481	0,72128	kg/m <sup>3</sup>
Ethanol inlet pressure	37,305	37,005	-0,80403	bar
Ethanol density	785,6435	786,156	0,065237	kg/m <sup>3</sup>
LOx mass flow ( $\Delta P$ )	3,43	3,4834	1,5583	kg/s
LOx mass flow (Coriolis)		3,375	-1,6029	
Ethanol mass flow ( $\Delta P$ )	2,15	2,1611	0,51464	kg/s
Ethanol mass flow (Coriolis)		2,1172	-1,5256	
Mixture ratio ( $\Delta P$ )	1,5953	1,6119	1,0383	—
Mixture ratio (Coriolis)		1,5941	-0,078473	

Table 4: Opening and closing times for propellant valves.

Event	Elapsed time from first command [ms]
VP25 open command	0
VP25 not closed	83
VP25 open	143
VP16 open command	50
VP16 not closed	133
VP16 open	213
VP25 close command	1752
VP25 not open	288
VP25 closed	2008
VP16 close command	1818
VP16 not open	1963
VP16 closed	2038

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## 2.2 Calculations

The characteristic velocity,  $C^*$ , is calculated by:

$$C^* = \frac{p_0 A^*}{\dot{m}}, \quad (1)$$

where  $p_0$  is the chamber pressure,  $A^*$  is the throat area and  $\dot{m}$  is the mass flow.

The combustion efficiency  $\eta$  is defined by the ratio of calculated characteristic velocity  $C^*$  and theoretical characteristic velocity  $C_{\text{theo}}^*$ :

$$\eta = \frac{C^*}{C_{\text{theo}}^*}. \quad (2)$$

The residence time is calculated by assuming the specific heats ratio is exactly the one calculated by CEA, hence focusing the combustion inefficiency in the product  $RT$ :

$$t = \frac{\text{Vol } \rho}{\dot{m}} = \frac{\text{Vol } p_0}{\dot{m}RT} \approx \frac{\text{Vol } p_0}{\dot{m}(RT)_{\text{theo}}\eta^2}. \quad (3)$$

In previous equations,  $p_0$  represents total (chamber) pressure; Vol represents the internal volume of the combustion chamber of the test subject (1,44ℓ);  $(RT)$  and  $(RT)_{\text{theo}}$  represent the actual and theoretical values of the product  $RT$  for the combustion gas, respectively.

The theoretical values used for reference in this report are calculated with the NASA CEA program. Measured chamber pressure and mixture ratio are used as input for CEA calculations. Table 5 shows the results of the analysis performed for this run.

In addition, the combustion roughness is calculated by taking the RMS from the high frequency pressure transducer in the interval between 0,9 and 1,2 seconds after ignition.

$$C_r = \frac{\sqrt{\sum (P - \bar{P})^2}}{\bar{P}}. \quad (4)$$

Table 5: Test data analysis.

Name	Calculation Method	Theoretical value	Calculated value	Error (%)	Unit
Characteristic velocity ( $\Delta P$ ) ( $C^*$ )	(1)	1719,8113	1669,342	-2,9346	m/s
Characteristic velocity (Coriolis)		1720,7486	1715,6303	-0,29744	
Combustion efficiency ( $\Delta P$ ) ( $\eta$ )	(2)	—	0,97065	—	—
Combustion efficiency (Coriolis) ( $\eta$ )		—	0,99703	—	—
Residence time ( $\Delta P$ ) ( $t$ )	(3)	0,5675	0,60233	6,138	ms
Residence time (Coriolis) ( $t$ )		0,5788	0,58226	0,59755	
Workability ( $\Delta P$ ) ( $RT$ )		1189,8122	—	—	kJ/kg
Workability (Coriolis) ( $RT$ )		1191,8024	—	—	
Adiabatic Coefficient ( $\Delta P$ ) ( $\gamma$ )		1,1284	—	—	—
Adiabatic Coefficient (Coriolis) ( $\gamma$ )		1,1293	—	—	—
Combustion Roughness ( $C_r$ )	(4)	—	1,3388	—	%

## 3 Observations

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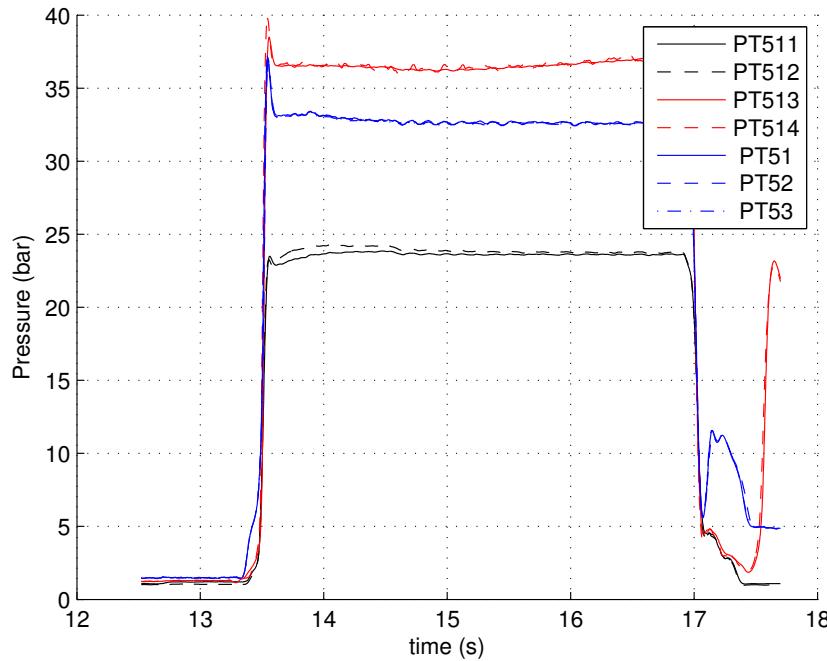


Figure 3: Test subject pressures during hot firing test.

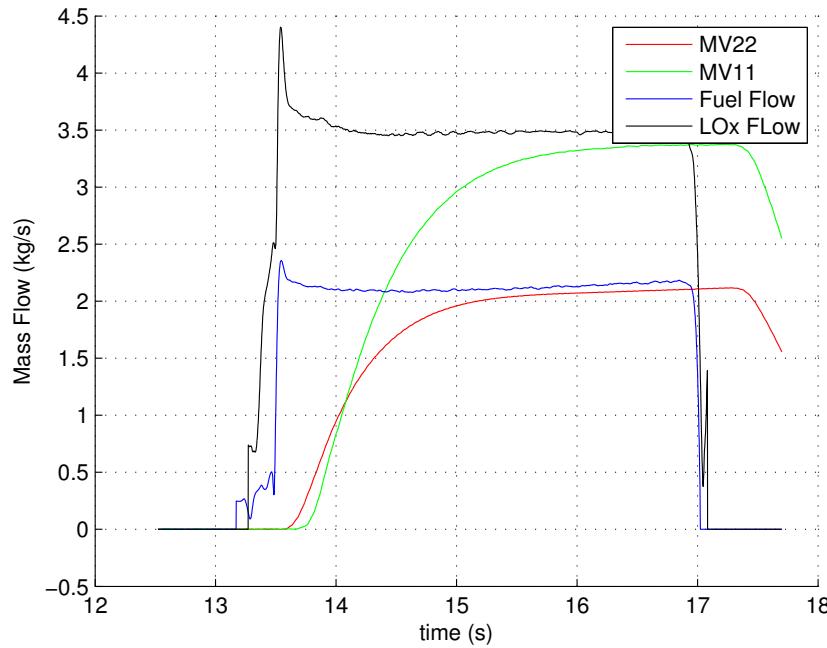
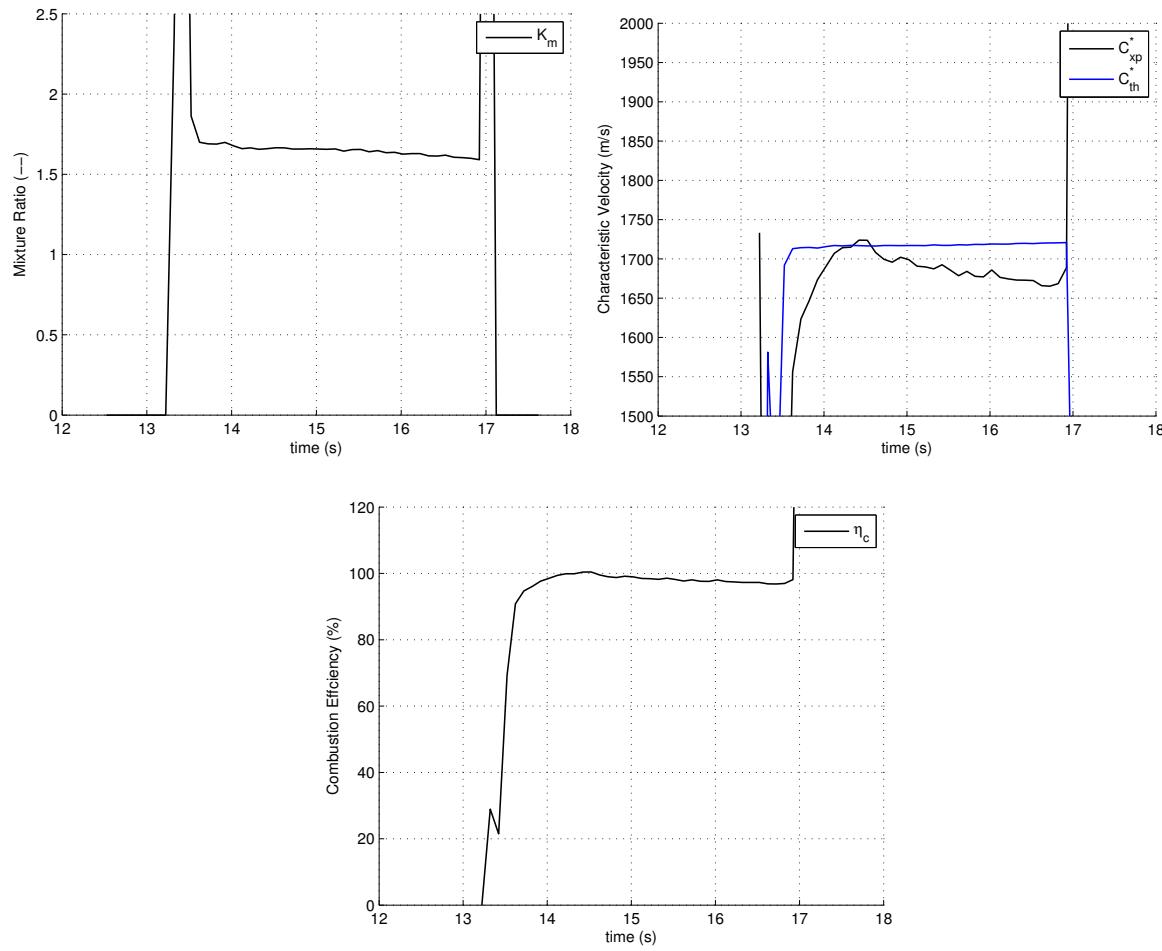


Figure 4: Test subject mass flows during hot firing test.

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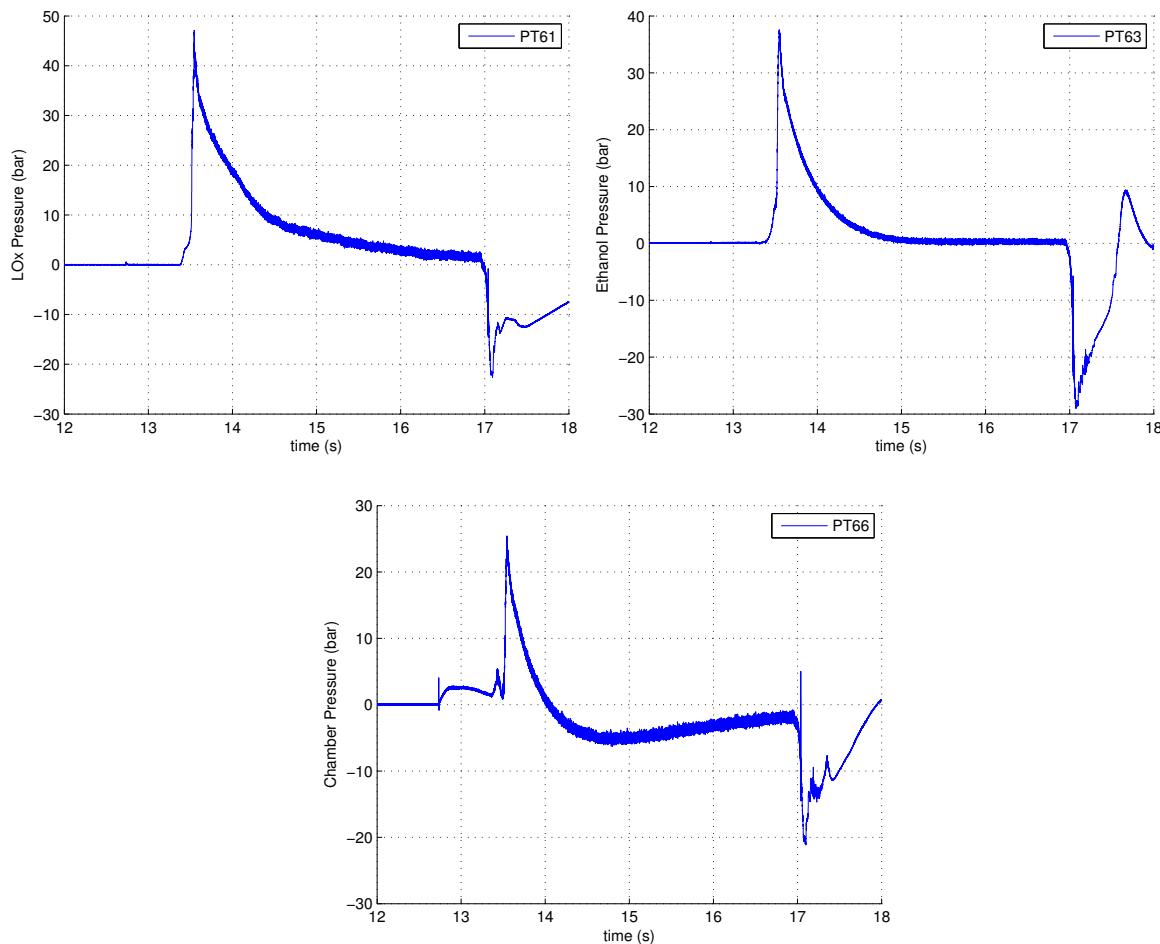


Figure 5: HF Pressure Transducers

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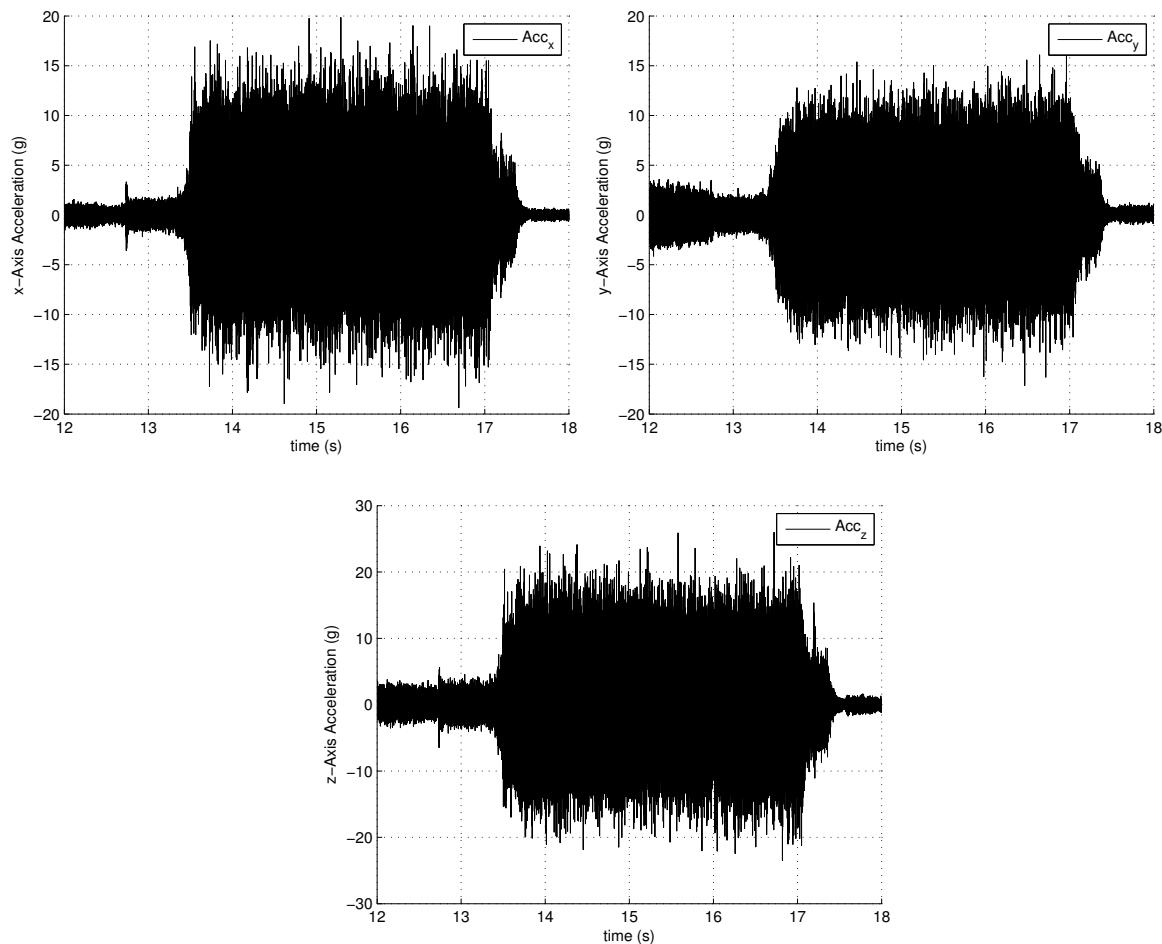


Figure 6: Accelerometers

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