

# Coursework 1

**Handout date: 8<sup>th</sup> February 2010**

**Submission date: 16:00hrs 8<sup>th</sup> March 2010**

All coursework must be submitted in English.  
Coursework that is not submitted by the due time and date will only be accepted if accompanied by a valid explanation.  
No coursework will be accepted more than a week after the due date under any circumstances. 10% will be deducted from the final mark for each day between the submission date and date of a late submission.  
Coursework will be screened for evidence of plagiarism. Any student who is found guilty of submitting plagiarised work will be awarded a mark of zero.  
The mark for this coursework contributes 15% to your overall mark for this module.

## ***Deliverables***

- Paper copies of answers to the following problem should be submitted before the submission deadline.

## ***The Challenger Explosion***

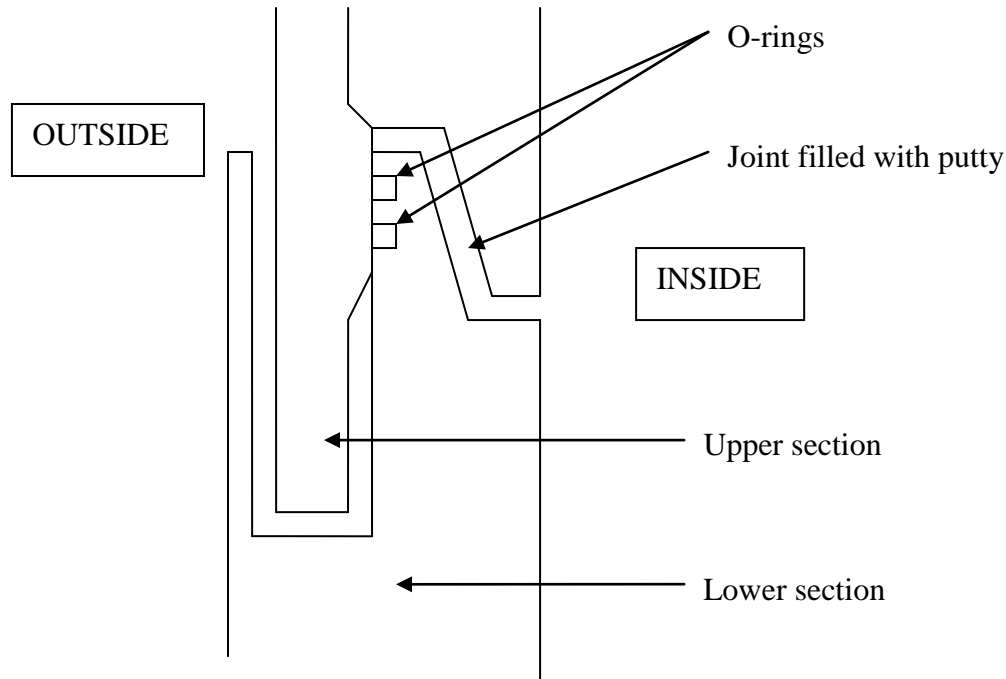
On the morning of January 28<sup>th</sup> 1986 the decision was made to launch the space shuttle Challenger (STS 51-L). The engineers at Morton Thiokol were unhappy about the decision but could not persuade managers that there was any possible danger in launching the shuttle. On launch, two rubber O-rings leaked and the shuttle exploded. The air temperature that day was approximately 30F.

The data presentations on the following pages were used in making the launch decision that morning. They contain all of the information necessary to demonstrate that launching the shuttle at such a low temperature was not a good idea.

## ***Background***

When it launches, the space shuttle has two solid rocket boosters (SRMs), A and B, on the right and the left of the main fuel tank. These are built in several different segments and then joined together. At each joint the top section slides into the bottom section and the joint is filled with putty to ensure a good seal. Two O-rings are also used as backup safety devices; if hot gas from the inside of the booster escapes through the putty then it will be stopped by the O-rings, which fit tightly all the way around the circumference of the joint (see diagram).

It is very important that the O-rings fit tightly, as any escape of hot gas from the booster would be catastrophic. They are made of rubber, which shrinks at low temperatures. If the temperature is low enough then they shrink so much that they no longer provide an effective seal. This is what happened to the Challenger – the O-rings failed and the booster exploded, destroying the shuttle with it.



*Simplified diagram of SRM joints*

### **Problem**

Watch the television documentary on the loss of the Challenger (available in Blackboard), then write a short report (2000 - 2500 words) that covers the following points:

- Explain what was wrong with the Morton Thiokol presentations.
- Explain and illustrate how you might use data selection and rearrangement to redesign the presentation of the data in order to make the correct decision (not to launch) more obvious.
- Create one or more diagrams that make clear the dangers of launching the shuttle at low temperatures.

The marking criteria given at the end of this document provide some information on what levels of detail are required for different grades.

### **References**

NASA Shuttle Mission Archive

<http://www-pao.ksc.nasa.gov/shuttle/missions/51-l/mission-51-l.html>

**History of O-Ring damage on field joints – SRM No. = launch number of shuttle**

**HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS**

SRM No.	Cross Sectional View			Top View		Clocking Location (deg)	
	Erosion Depth (in.)	Perimeter Affected (deg)	Nominal Dia. (in.)	Length Of Max Erosion (in.)	Total Heat Affected Length (in.)		
61A LH Center Field**	22A	None	None	0.280	None	None	36° -- 66°
61A LH <del>CENTER</del> FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338° -- 18°
51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25	163
51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75	354
51C RH Center Field (sec)***	15B	None	45.0	0.280	None	29.50	354
41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None	275
41C LH Aft Field*	11A	None	None	0.280	None	None	--
41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50	351
STS-2 RH Aft Field	2B	0.053	116.0	0.280	--	--	90

*Handwritten notes:* Oct 30, 1985 (next to 61A LH Center Field); AFT (next to 61A LH Center Field); 85 (next to 51C LH Forward Field); 100 (next to STS-2 RH Aft Field).

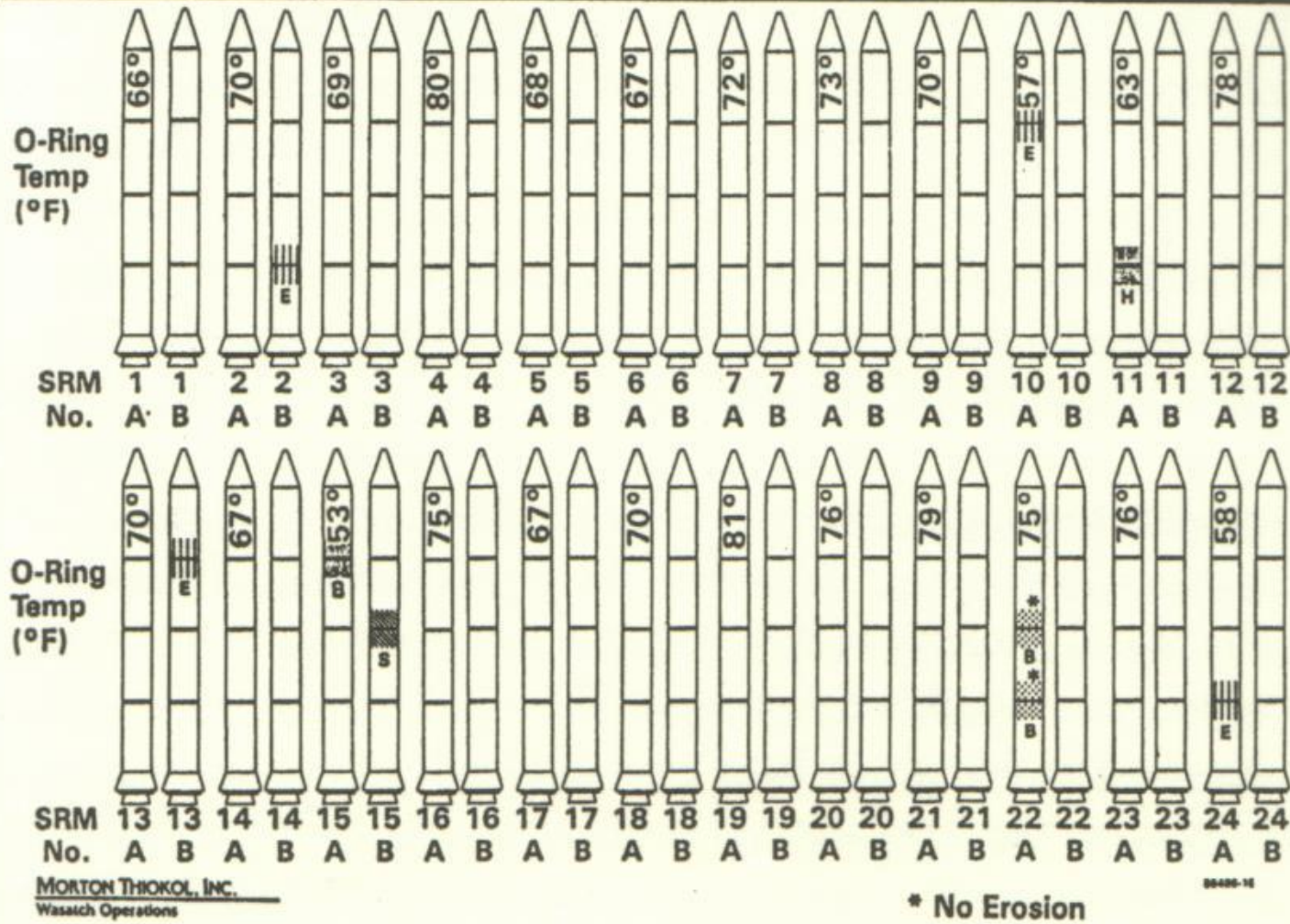
\*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.  
 \*\*Soot behind primary O-ring.  
 \*\*\*Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

### History of O-Ring Damage in Field Joints (Cont)



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\* No Erosion

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INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE ORAL DISCUSSION

BLOW BY HISTORY		HISTORY OF O-RING TEMPERATURE (DEGREES - F)				
SRM-15 WORST BLOW-BY		<u>MOTOR</u>	<u>MBT</u>	<u>AMB</u>	<u>O-RING</u>	<u>WIA</u>
<ul style="list-style-type: none"> <li>○ 2 CASE JOINTS (80°), (110°) <u>ARC</u></li> <li>○ MUCH WORSE VISUALLY THAN SRM-22</li> </ul>		DM-1	68	36	47	10 m
SRM 22 BLOW-BY		DM-2	76	45	52	10 m
<ul style="list-style-type: none"> <li>○ 2 CASE JOINTS (30-40°)</li> </ul>		QM-3	72.5	40	48	10 m
SRM-13A, 15, 16A, 18, 23A 24A		QM-4	76	48	51	10 m
<ul style="list-style-type: none"> <li>○ NOZZLE BLOW-BY</li> </ul>		SRM-15	52	64	53	10 m
		SRM-22	77	78	75	10 m
		SRM-25	55	26	29	10 m
					27	25 m

AMB – Ambient temperature

O-RING – temperature at the O-Ring itself

### Marking criteria

The following grid shows what is expected in answers to this coursework:

QUESTION	EXCEPTIONAL 9-10	MERITORIOUS 8,8.5	HIGHLY COMPETENT 7,7.5	COMPETENT 6,6.5	PASS 5,5.5	FAIL 0.5-4.5
1) Description of what the Morton Thiokol engineers did wrong	Provides detailed breakdown of cognitive errors in data presentation	Explains the main problems in terms of cognitive processes	Explains the lack of linkage between the two sets of data	Explains that diagrammatic method used is not suitable for the task	Highlights the lack of structure	Provides no reasons why the original presentation was weak
2) Visual presentation of data	Diagrams provide predicted values for catastrophic failure with ranges	Diagrams are clear, well-structured and make it obvious that the failure is likely	Diagrams include erosion data	Diagrams show increased likelihood of risk at low temperatures	Diagrams based purely on number of failures	Diagram shows no increased risk at low temperatures
3) Explanation of why new presentation is better	Provides detailed breakdown of cognitive support in data presentation	Explains the main advantages in terms of cognitive processes	Provides some method of linking the two data sets	Explains why the chosen graphical method is better than the diagrams used	Highlights the advantages of a structured approach	Provides no reasons why this presentation is better