Development of Reliability Model for Furnace System using Spreadsheet

by

Muhammad Syafiq bin Mohd Johari

Dissertation submitted in partial fulfilment of
The requirement for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr Ainul Akmar binti Mokhtar)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD SYAFIQ BIN MOHD JOHARI

ABSTRACT

The Oxford English Dictionary defines a furnace as ‘an enclosed structure for intense heating by fire, esp. of metals, or water’. Other definition defines furnace tubes as an electric heating device used to conduct syntheses and purifications of inorganic compounds and occasionally in organic synthesis. (8) There were many types of furnace available today such as pyrolysis furnace, steam reformer furnace, heating furnace etc. Furnace functions to heat the sample in order to change the product form such as from liquid to gas or from solid to liquid form. Furnace in industry contain tube which functions at a very high temperature up to 1250^{o}C and more to heat the chemical and the furnace system in order to change the product type. The high temperature operation causes the tubes to experienced tube expansion or creep. Inspection data will be taken from each tube in order to analyze the expansion of tube’s wall thickness. The tube’s maximum growth will be different based on the position of tubes. The data will measure the expansion in tubes internal diameter and external diameter. Analysis is conducted based on the inspection data to predict on growth rate, time to failure and also reliability of the system. The reliability is importance to foresee the availability of the furnace system to be used and to predict the time to replace of new one. From the data, the author can form a failure distribution graph which will show the pattern of growth from the tubes system.

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I would like to take this opportunity to thank God for His guidance and blessings and to all parties who had assisted me in making my Final Year Project as a success.

I want to express my sincere appreciation to my FYP Supervisors, Dr Ainul Akmar binti Mokhtar for her moral support and continuous supervision throughout the 2 semester of the project. Under her supervision, I was able to understand the topic although the topic has not been taught till in the final semester. Her kindness and relentless support towards her students show that her passion in moulding a better and educated younger generation that will someday be future leader and renown figure in the working industry.

I would also like to express my deepest and heartfelt appreciation to my family and friends for their continuous support throughout the project. With their support, I was able to learn a lot regarding the topic and was able to finish the project within the time given. Their comment and positive criticism have also helped me in improving my work and keep me in check with my project progress.

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NOMENCLATURE OF ABBREVIATION

EPMSB	Ethylene Polyethylene Malaysia Sdn Bhd
PETRONAS OPU	PETRONAS Operating Unit
UTP	Universiti Teknologi PETRONAS
NDT	Non-Destructive Testing
SEM	Scanning Electron Microscope
ASTM	American Society for Testing and Materials
RAM	Reliability, Availability and Maintainability
k	Number of Failed Sample
n	Total Number of Sample
Q_s	Reliability of the system
P_s	Probability of the system
OD	Outer Diameter
ID	Internal Diameter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

Steam reformer furnace is widely used in most petrochemical processing plants. The function of the tubes inside the furnace is to change the phase of the hydrocarbon flowing inside the tubes to form a desired product. To do this, the steam reformer furnace has to operate at a very high temperature that ranges from 500°C up to 1300°C. After being in this condition for a long period of time, the tubes typically experience some damages that eventually leading to failure. High temperature condition creates coke formation and the coke formation will expand the tube leading to surface cracking, intergranular corrosion and other defects on the surface of the tubes and hence affects the performance of the steam reformer furnace. The current practice in monitoring the performance of steam reformer furnace is by the tube condition where the tubes are visually checked and the tube wall thickness is measured. The inside and outside diameter of the tubes are then compared to the design diameter. In other words, the tube growth or expansion is being assessed and the inspection/maintenance plan is being developed.

1.2 PROBLEM STATEMENT

At the moment, in PETRONAS OPU's, the practitioners do not calculate the system reliability of steam reformer furnace. This assessment is seen to be important to the author as it will assist the decision-making process whether to down the steam reformer furnace or not. Furthermore, there is no tool to calculate the system reliability of the steam reformer furnace using the available inspection data. Thus, there is a need to develop a practical tool to do such calculation.

1.3 OBJECTIVE

1) To identify the system design of the steam reformer furnace and the decision criteria for stating the system is up or down.
2) To develop a reliability model for the steam reformer furnace using a spreadsheet.

1.4 SCOPE OF STUDY

The project objective is to develop a steam reformer tube simulation and reliability calculation as a reference for furnace users. The project will be focused on tube expansion which is creep failures which are under mechanical fail of the furnace system. The study of the development of tubes simulation and reliability based model are based on inspection data from PETRONAS Ammonia Sdn Bhd. The calculation and analysis to develop a reliability based model are based on tubes internal and outer diameter from the inspection results. Figure 1 shows the failure that may occur to the furnace system.

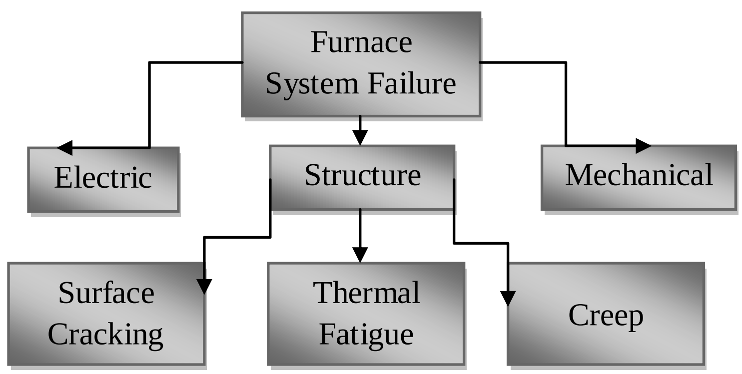

Figure 1: Failure in Furnace System

Prediction of failure is very important to ensure the safety during the operation. Reliability is applied in assuming the failure probability of the system based on calculation and past scenarios. The creep failure that will be discussed in this study is about tubes expansion and rate of growth to predict tube's lifespan.

1.5 RELEVANCY OF THE PROJECT

Development of reliability model of steam reformer furnace using spreadsheet is related to the industrial based engineering work. The reliability is very important in foresees the future of the machine or system based assessment, inspection data and experience of users. The result or report of this research will be used by the industrial practitioners for the reference in plant related or to be improved. The improvement will be made in term of other study case, cost and effect on other causes.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 FURNACE IN PETROCHEMICAL PROCESSING PLANT

Application or function of furnace tube or steam reformer in petrochemical processing plant is to process hydrocarbon and methane to form a desired product. The feed materials natural gas, liquid gas or naphtha are endothermically converted with water steam into synthesis gas in catalytic tube reactors. Process heat as well as flue gas are used for the steam generation. The desulphurized hydrocarbon feed is mixed with superheated process steam in accordance with the steam/carbon relationship necessary for the reforming process. The superheated steam is the technology where the drying takes place through direct contact between superheated steam and the product to be dried. Drying with superheated steam is an emergent technology with big potential advantages with respect to energy saving, emission reduction fire and explosion prevention and product quality.

After the process heat or steam generation finish, this gas mixture is heated up and then distributed on the catalyst-filled reformer tubes. The gas mixture flows from top to bottom through tubes arranged in vertical rows. While flowing through the tubes heated from the outside, the hydrocarbon/steam mixture reacts, forming hydrogen and carbon monoxide in accordance with the following reactions:

$$C_nH_m + n\,H_2O \Rightarrow n\,CO + ((n+m)/2)\,H_2 \qquad (1)$$

$$CH_4 + H_2O \Leftrightarrow CO + 3\,H_2 \qquad (2)$$

$$CO + H_2O \Leftrightarrow CO_2 + H_2 \qquad (3)$$

To minimize the methane content in the synthesis gas while simultaneously maximizing the H2 yield and preventing the formation of elemental carbon and keeping it from getting deposited on the catalyst, the reformer is operated with a higher steam/carbon relationship than theoretically necessary.

As the heat balance for the main reactions (1) to (3) is endothermic, the required heat must be produced by external firing. The burners for the firing are arranged on the ceiling of the firing area between the tube rows and fire vertically downward. The residual gas from the pressure swing adsorption unit as well as heating gas from battery limits is used as fuel gas. The flue gas is then cooled down in a convection zone, generating steam.

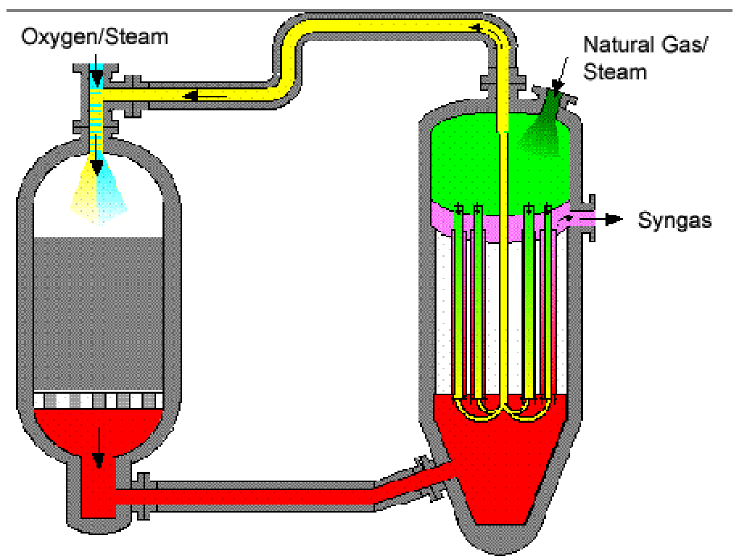

Figure 2: Process of hydrocarbon steam mixture in tube reactors (Tandem Reforming.2012)

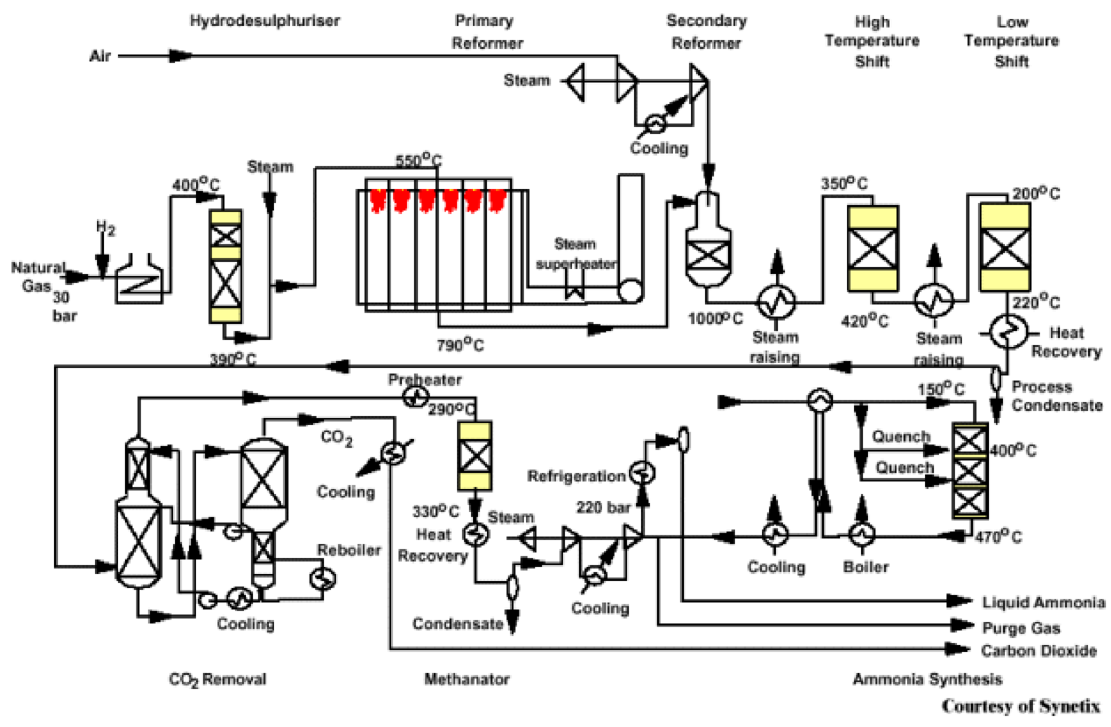

Figure 3: Steam Reforming Plant Layout (Reforming Section Development)

2.2 STEAM REFORMER FURNACE

Steam Reformer Furnace has same application with pyrolysis furnace system, but these types of furnace have hundreds of tubes which are filled with catalyst. The tubes are made of cast HP-microalloyed grade 35Ni25Cr1NbTi alloy used in the primary reformer furnace section. Alloy is used in order to resist high temperature and pressure application instead of long lasting and low corrosion rate. This catalyst filled process heater tubes processing natural gas and steam reforming reaction in petrochemical industry. The number of tubes for the furnace depends on the function and its application, but all of the tubes are assemble and work in one machine. Figure below shows a research on reliability of a furnace tube arrangement consists of 456 tubes in two cells.

1	**2**	**3**	**4**	**.................**	**114**
115	**116**	**117**	**118**	**.................**	**228**

229	**230**	**231**	**232**	**.................**	**342**
343	**344**	**345**	**346**	**.................**	**456**

Figure 4: Tube arrangement for 456 tubes in a Furnace (M.Zuo. et al. 1999)

The chemical flow inside the tube can be natural gas, liquid gas or naphta. The chemical are converted endothermically with steam into synthesis gas in catalytic tube reactors. Process heat as well as flue gases are used for generation of steam. In the process, the chemical is sent through inlet pigtails are connected to inlet headers batch-wise. The passing through the feed and heating of the tube will cause the tube to fail.

2.3 STEAM REFORMER TUBES DEFECT AND FAILURE ANALYSIS

Steam Reformer Furnace operates at a very high temperature in a petrochemical processing plant. It is used to change the chemical to another phase and to another form of product by reaction. The major component in the steam reformer is tubes, steam reformer usually have hundreds to thousands of tubes in a shell. Failure in tubes is very serious problem which will lead to the failure of the steam reformer. Thus, there were a few steps introduce by the researcher to guide in failure analysis study. The first step in conducting any failure analysis is to gain a good understanding of the conditions under which the part was operating (Davidson.T.1999). Thus, the condition of the steam reformer is already stated above. The investigator must know the detail condition of the steam reformer such as how it has been handled, how many hours of operations, what temperature is applied, what chemical is used inside the tubes etc. After the investigator understands deeply on the environment of the steam reformer, the sample is taken out from the steam reformer such as sample tubes from many positions in order to detail investigation on tubes failures.

All samples will be labeled accordingly in order to know the effect of position in tube’s defect. Visual examination is conducted in order to predict the defect occur to the surface of the sample. The sample should be recorded before and after any steps conducted such as surface cleaning, etching etc. After the visual examination is conducted by procedure, the next step is to conduct the detail analysis on the tube sample. There were five (5) tests need to be conducted to the tube sample which are macroscopic examination, non-destructive testing (NDT), chemical analysis, metallographic examination and mechanical testing.

Many of these examinations require steps that used the same equipment and therefore much time can be saved with a little forethought. Microscopic examination is best performed when cataloguing the sample, but the investigator usually wants to see more detail picture into the sample. Thus, in investigating more detail defect into the sample, Scanning Electron Microscope (SEM) is used with a higher magnification compared to Optical Microscope. Non-Destructive Testing (NDT) such as ultrasonic testing, radiographic testing, dye penetrant test is used to parts defects without damaging the sample. Results obtained from NDT can be used to examine parts in the field and removed them from service before failures occurs. In the other hand, chemical analysis is done on the bulk of materials to confirm the material composition. Chemical analysis used chemical to detect the material or element inside the sample by reaction of a catalyst. Other than that, metallographic testing involves the sectioning of samples to examine the microstructure. The sample needs to be examined for the whole surface in order to detect crack in microstructure in a bigger view. The result obtained from this examination such as intergranular cracking which occur in the sample grain boundaries. Lastly, mechanical properties is conducted to conform the sample is following the standard according to ASTM or any other standards. Hardness test is one of the mechanical tests to examine the hardness of the sample. Other than hardness, mechanical testing will test on young modulus and stress strain analysis.

Once the data is gathered, the investigator needs to analyze and come out with the conclusion on the defect, failure and other findings along the investigation in tube sample. Then, the investigator need to prepare recommendations as a reference for the next generation. The recommendation will not be taken lightly, serious failures can occur if recommendation are in error.

2.4 TUBE FAILURE TRACKING METHOD

The inspection of steam reformer tubes consist of two methods which are using LOTIS and MANTIS examination instead of using Non Destructive Testing (NDT) through the sample.

LOTIS and MANTIS examination collects million of data through one scanning process per tube which give a good result and deep analysis about the tubes failure and defects. Data point from the internal surface from the reformer tube which can be modeled to provide powerful visual aids necessary to make operational, mechanical or design changes to increase the efficiency and performance of the steam reformer (Richard.D.Roberts.2005). Internal inspection is carried out during the turn around when the reformer catalyst is being changed and it takes less than 3 minutes per tube to be inspected. The LOTIS experiment used laser based surface mapping to scan all the surface in order to detect the defect, crack and also surface growth. The LOTIS probe projects a small laser beam onto the target surface, this provides precise radius measurements to 0,05mm of the inside surface of the tube at each sample point, which for a typical 100mm internal diameter tube means creep strain is quantified to within 0.05% (Richard.D.Roberts.2005).

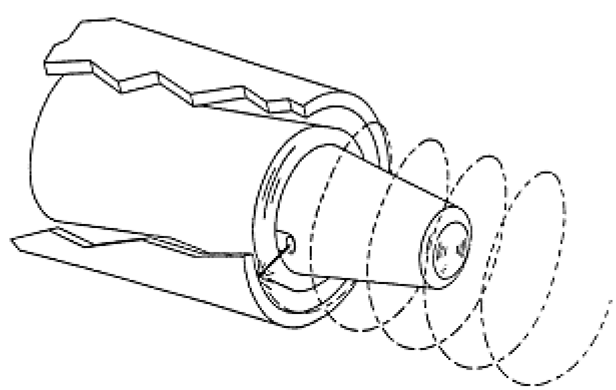

Figure 5: Helical Path Scan Illustration (Richard.D.Roberts.2005)

Data collected from each tube is the wall thickness measures from the inside diameter and outside diameter. The laser scanning detects the thickness of wall and the position of the thickness is measured. Then, the thickness is analyses and the percentage of growth or the growth rate of the wall can be calculated.

2.5 RELIABILITY ANALYSIS ON STEAM REFORMER TUBE

Based on PETRONAS definition, reliability is defined as a probability that a component or system will perform a required function for a given period of time when used under stated operating condition. By definition, this study of reliability on steam reformer furnace is to analyze the probability of the steam reformer to operate in a calculated remaining life. Reliability of steam reformer will be assessing in term of tube's reliability as a whole system because the function of tubes will determine the survival of that equipment. Steam reformer consists of hundreds up to thousands of tubes in a row and column. Thus, the general reliability calculation such as total number of failed tubes over total number of tubes might not be reliable. Thus, reliability of the steam reformer tube is best to be calculated using k out of n system. K out of n system method is a method in calculating probability of a system. K is defined as the number of failed system and n is defined of the total number of system available. A n-component system that fails if and only if at least k of the n-component fail. Based on this definition, k out of n can be simplified as (n-k+1) out of n system. The term k-out of n system usually used to determine the function of two or more system. Since value of n is larger than k, redundancy is generally built into a k-out of n system.

With the k-out of n system, it can be same applied to the steam reformer which consists of a lot of tubes. By using this method to the tubes, consider a general system which consists of a sequence of n components where each component is put to function fails. The component will be numbered accordingly and the failure is measure if and only if k numbered tube fail. Thus, all the tube need to be evaluated in order to determine how many tubes can be fails in order for the whole system fails.

In developing reliability model of a steam reformer by using k-out of n method, a few formula and calculation need to be used. Some general terms were used in developing reliability by using k-out of n method as follows:

Symbol	Description
R(t)	system reliability at time t depending on design vectors z and n
n	n = (n1; n2; : : : ; ns)
ni	number of components used in subsystem i
nmax;i	upper bound for ni(ni _ nmax;i8 i)
z	= (z1; z2; : : : ; zs)
zi	index of component choice used for subsystem i, zi 2 f1;2; : : :;mig
mi	number of available component choices for subsystem i
k	k= (k1; k2; : : : ; ks)
ki	minimum number of operating components for subsystem i
s	number of subsystems
Tij	time-to-failure of the jth available component for subsystem i
ijג	component failure rate (exponential distribution parameter) for the available component for subsystem i, fij(t) = _ij exp(−_ij t)
C, W	system-level constraint limits for cost and weight
cij , wij	cost and weight for the jth available component for subsystem i
t	mission time (_xed)

Table 1: Terms used in probability calculation (The K-out of N system model)

From the study case, there were 4 rows and 114 column in a steam reformer furnace all together interconnected in one shell. By using k-out of n system model, the reliability calculation is assigned based on a few scenarios (M.Zuo.1999).

Scenario	Condition	Example
Scenario 1	The furnace is failed if at least a certain number of tubes are failed	10% from total number of tubes failed, consider the whole system failed
Scenario 2	The furnace is failed if at least one cell has at least a certain number of tubes that are failed	5% from the total number of row failed consider the whole system failed
Scenario 3	The furnace is failed if at least one row has at least a certain number of consecutive tube failures	5 series of tubes failed in a row consider the system in a row failed

Table 2: Assigned scenario for reliability calculation (M.Zuo.1999)

The probability is calculated based on derivation from above terms. The result of the reliability will be getting either in which condition or scenario the furnace tube fail causes the whole system can be failed.

Other than that, reliability of the system can still be calculated generally by ignoring the assign scenarios (M.Zuo.1999). General formula to calculate system reliability of steam reformer as follows:

$$\text{System Reliability, } Q_s = \frac{\text{No. of failed tubes}}{\text{Total no. of tubes}} \quad (1)$$

From the reliability results, probability of a system to fail will be:

$$\text{Probability of a system to fail, } P_s = 1 - Q_s \quad (2)$$

From the system reliability and probability, the researcher can come out with general conclusion either the system down or still reliable to operate or the system can operate with a condition.

CHAPTER 3
METHODOLOGY

3.1 PROJECT ACTIVITIES

In order to develop the reliability model for the steam reformer furnace, the following activities are carried out as shown in Figure 8.

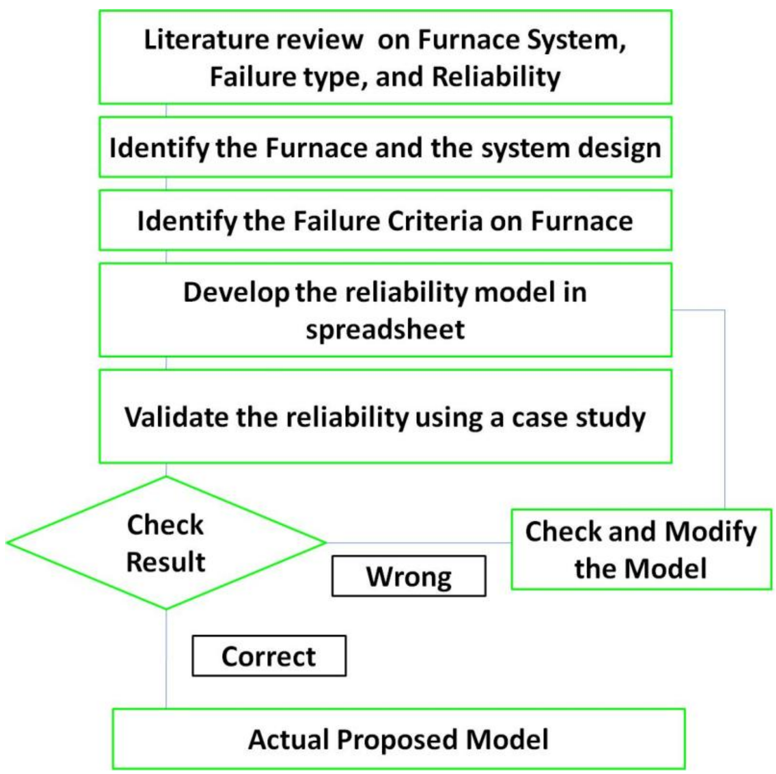

Figure 6: Project Work Flow

3.2 GANTT CHART

Based on the proposed methodology in Figure 8, the following Gantt chart or timeline is proposed in order to make sure the research will finish on time and in well manner.

Final Year Project 1														
Task	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title allocation	■													
Research on Furnace tube, tube failures and Reliability		■	■	■	■									
Reseacrh on Methodology				■	■	■								
Extended Proposal Submission							■							
Identify Furnace System and Design of the system								■	■	■				
Identify Failure criteria on Furnace System									■	■	■	■		
Proposal Defense										■				
Develop reliability of the system in spreadsheet											■	■	■	■
Interim Report Submission													■	
Final Year Project 2														
Validate Reliability using case study	■	■												
Check and Modify Result based on Proposed model		■	■											
Proposed Standard Model Template			■	■	■									
Case study data simulation					■	■								
Verification of Case Study data Result							■							
Progress Report Submission								■						
Pre-EDX										■				
Dissertation Writing									■	■	■			
Draft Report Submission											■	■		
Dissertation Submission (Softbound)													■	
Technical Paper Submission													■	
Oral Presentation														■
Dissertation Submission (Hardbound)														■

Figure 7: Gantt Chart

3.3 MODEL DEVELOPMENT METODOLOGY

3.3.1 Research on literature on Furnace System, Failure Analysis, and Reliability

Research on the steam reformer furnace is done to understand the concept, structure, type and mechanism of the steam reformer as well as its function in industry. Knowing the operating condition and design of steam reformer is very importance in developing the steam reformer model in spreadsheet. Based on the literature review, the largest steam reformer presents in industry is having 2000 tubes attached in one shell (Davy Powergas Inc). Thus, the design of steam reformer model in the spreadsheet is on maximum for 2000 tubes available. Failure analysis is a study about tube failures, type of failures occurs to the tube and the criticality or life span of the tube. In this research, the tube failure is focus on creep or tube expansion in order to calculate the reliability and to determine the availability of the tube at that instant. Study on the reliability of the furnace tube is about assessing the fail tube. The fail tube will be calculated on the probability depending on assign scenario in order for the whole system to be fail. Thus, by studying on the operational condition, failure criteria and analysis as well as reliability of the steam reformer, the system or model can be applied in the case study.

3.3.2 Identify Furnace System and Design of the System

Identifying the furnace system is first knowing the type of furnace either the system is pyrolysis furnace or steam reformer furnace. According to the research paper by M.Zuo et al, the furnace used in steam reformer furnace which contains three furnaces which labeled furnace 1, 2 and 3. Furnaces labeled 1 and 2 have same number of tubes which are 456. The tubes were arranged in 2 cells and each cell has 2 rows.

Thus, this is a sample design of the furnace system need to be identified. Then all the data will be input in the spreadsheet and the reliability will be calculated based on the formula of k-out of n method. The other furnaces have 368 tubes in 46 x 8 cells. This research focus on the steam reformer design which is the number of tubes. The tubhes model developed in the spreadsheet by using formula (1) will be applied to the inspection data from PETRONAS Ammonia Sdn Bhd.

3.3.3 Validate the Reliability using Case Study

To develop reliability model using spreadsheet, the author used a case study by M.Zuo et al. (1999). The first step is to identify the furnace system. The furnace is the steam reformer furnace used to have 4 rows x 114 columns. In the other hand, the design of the system will be created in maximum for 2000 tubes based on the literature review. Thus, the user needs to key in the number of row and number of column in order to determine the design arrangement of the tube.

Please insert value in Blue Box

No. of Row	10
No. of Column	200
no of tube	2000

Figure 8: User Input Box

After the user key in the number of row and column, the design of the tubes and cell tube arrangement will form as in Figure 11. One cell represent one (1) tube and the below box will represent the status of the. The formula is coded into each cell in order to link with the user input box. The color of the in the box indicates that the failed and the pass tubes which the author already assign “1” as the pass tube represent by green color and the “0” as the failed tube represent blue color. Thus, the user can directly identify roughly the distribution of the pass and failed tube. The formula used to develop the tube model is as follow:

Tube Number = IF (J17=C17-1,C17,IF(J17<C16,1+J17," ")) (3)

1	2	3	4	5	6	7	8	9	10
1	0	0	0	1	0	1	1	1	1
201	202	203	204	205	206	207	208	209	210
0	0	0	1	1	1	1	0	0	0
401	402	403	404	405	406	407	408	409	410
1	1	0	0	0	0	1	1	0	1
601	602	603	604	605	606	607	608	609	610
1	0	0	1	1	1	0	1	1	0

Figure 9: Steam Reformer Tube Model

3.3.4 Assessing the reliability of the Furnace system

In order to calculate and assess the reliability based on scenarios by M.Zuo et al (1999), the author converts from M.Zuo et al (1999) study into spreadsheet formulation. The following explanation is about assessment of the steam reformer tube's reliability based on scenarios. The assign scenarios are as follows:

Scenario 1: The furnace is failed if at least a certain number of tubes are failed

In this scenario, the minimum number of tube fail to sustain the operability of the system is assumed to be 10% which are 45 tubes fail out of 456 tubes. Thus, the system is calculated as per formula below:

$$Q(k,n) = p_n Q(k, n-1) + q_n Q(k-1,n-1) \qquad (4)$$

Where, $Q(k,n)/q_n$ = reliability of the system

$p_{n\,=}$ Probability of the system

k = Number of failed tube

n = Total number of tube

From the equation, the reliability of the system can be obtained by using Eq.1 and the probability of the system can be calculated by using Eq.2.

Scenario 2: The furnace is failed if at least one cell has at least a certain number of tubes that are failed

In this scenario, the authors highlighted each row must be failed at maximum 12 tubes which is 5% per total number of tube in order to sustain the functionality of the system. In order to determined either the system fail or not, if else function is used. The authors determined that if more than half of the row fail or three out of four rows fail then all of the system will be failed. In the other hand, if only one row failed and the other pass, means the system still reliable to be operate. Then, in order to determine the furnace failure probability, the following formula has been used in the spreadsheet:

$$Q_s = Q_1 + Q_2 - Q_1Q_2 \quad (5)$$

$$Q_1 = Q_1\,(k_{1,}\,n_1) \quad (6)$$

$$Q_2 = Q_2\,(k_2,\,n_2) \quad (7)$$

In this case, Q_1 and Q_2 denoted as reliability at row 1 and 2 and Q_s is the reliability of the system while the probability of the system can be calculated as Eq.(2).

Scenario 3: The furnace is failed if at least one row has at least a certain number of consecutive tube failures

In this case, author assumes five (5) consecutive tube failures in each row which cause all the row fails. This condition is almost different to scenario 1 and scenario 2. Assume if only five (5) consecutive tube fail in one row and total of the tube fail in the system referring to this case study is 20 tubes, so 20 tubes still not meet 10% out of the total number of tubes. In this case, the row still failed if and only if five (5) consecutive tubes failed in one row because in theory of parallel arrangement of tube, failed tubes unable enough heat to the system cause the process incomplete.

Reliability for each row must be calculated and the reliability of the system will be determines by the product of each row's reliability. Each of the cell need to be total up in order to get summation of the five (5) consecutive cells is zero (0).

Calculation for the system can be simplified as follow:

$$SUM_n = (Cell_1+Cell_2+Cell_3+Cell_4+Cell_5) \quad (8)$$

$$\text{Row Reliability} = \text{IF((SUM=0,5,0)/total number of tube in row)} \quad (9)$$

$$\text{System Reliability, } Q_s = Q_{r1} \times Q_{r2} \times Q_{r3} \ldots Q_{rn} \quad (10)$$

Where Q_r = Reliability at row

Then, the probability for a system to is equal to Eq.(2).

After all the scenario has been assess, the formula used to combine the reliability is:

$$\text{Reliability of the system, } Q_s = Q_{s1} \times Q_{s2} \times Q_{s3} \quad (11)$$

Where $Q_{sn,}$ = reliability at scenario.

Based on the formula develop on three (3) scenario, a spreadsheet simulation is develop as per Figure 10. At the end of the assessment, the steam reformer model will shows the reliability of the whole system based on these three (3) scenarios and also the conclusion either the system is passed or failed.

Scenario 1 10% out of 288

Q(k,n)	
P n	0.583333
Q n	0.416667
Q (k n-1)	
Q (k-1 n-1)	
k	190
n	456
result	0

Scenario 2 5% out of 144

P n	0.9702586
Q s	0.0297414
k (1)	23
k (2)	23
n	456
result (k1)	1
result (k2)	0
results	

Scenario 3 5 consecutive tubes failed

P i	0.9999963
q i	3.701E-06
n r	114
k r	> 4
results	0

Figure 10: Reliability Tabulated Calculation Based on Scenario

3.3.5 Tool Required

In order to develop a reliability model based on the probability calculation, software needs to be used to shape a reliability model or bell curve graph. Microsoft Excel 2007 is used to develop the tubes simulation, reliability calculation based on scenario as well as assessment on inspection data such as tabulation of data, graph and calculation. In order to make this system into user friendly version, Visual Basic is used to make it more colorful and easier for the user to use it.

CHAPTER 4

RESULT AND DISCUSSION

After determining the parameter and steps involve in developing the tubes simulation in spreadsheet, the inspection data need to be analyze in order to get more detailed result and understanding on the creep on tube. A few analyses conducted based on inspection data such as effect on tube expansion versus position in tube, growth rate versus lifespan of tube and distribution of tube growth (PETRONAS Ammonia Sdn Bhd.2011). After all the analyses conducted and well discuss, the result will be applied to the tubes model based on three (3) scenarios (M.Zuo.1999). Finally, the reliability result will be compared between general calculations on reliability to the scenario calculation on reliability.

4.1 Percentage of Growth Vs Tube's Lifespan

Based on the data from PETRONAS Ammonia Sdn Bhd, the data consist of detail on steam reformer furnace tubes and also inspection results which shows a position in maximum and minimum diameter growth in the tubes. Even the maximum and minimum tube growth might be in different position, thus it is consider the percentage of growth for the entire surface of the tube as the tubes function in series as explain in 4.1. The maximum and minimum tube thickness is calculated and compared to the actual thickness which is 33mm (PETRONAS Ammonia Sdn Bhd.2011).The tube will be calculated based on percentage of growth, and the tube which exceeds the percentage of growth will consider fail. Each tube has different maximum percentage of growth (Refer appendix for data table), thus each tube will be calculated to determine the percentage tube growth. Percentage of growth is calculated as follows:

$$\text{Percentage of Growth (\%)} = \frac{\text{Max. OD} - \text{Min. OD}}{\text{Min. OD}} \times 100 \qquad (12)$$

Percentage of growth versus tube's lifespan is conducted in order to forecast the maximum years of this system can operate in industry before it failed. This study is conducted from the given tube detail and inspection data such as calculation for growth rate and remaining life for each tube (refer appendix). The growth rate is determined from the operation life for the system which is three (3) years and the minimum thickness is taken from the inspected data. The general formula for corrosion rate and remaining life calculation as below:

$$\text{Growth Rate (mm/year)} = \frac{\text{current thickness (mm)} - \text{Initial thickness (mm)}}{\text{Years of Operation (years)}} \tag{13}$$

$$\text{Remaining life (yrs)} = \frac{\text{Current thickness (mm)} - \text{Min. thickness (mm)}}{\text{Growth Rate (mm/years)}} \tag{14}$$

or

$$\text{Remaining life (yrs)} = \frac{\text{Max. Thickness (mm)} - \text{Current thickness (mm)}}{\text{Growth Rate (mm/yrs)}} \tag{15}$$

Thus, from the calculation result (Refer Appendix), the highest growth rate for the function tube is 1.00mm/years which is tube number 181. The failed tubes will give negative result as the remaining life calculation will also give negative answer. The failed tube will consider 0.00 years remaining life as the tube are already failed at this instant. On the other hand, the slowest growth rate from all the tubes involve is 0.03mm/years which is tube number 124. There were two tubes which are tube number 71 and 99 have no change after three (3) years operation, these two (2) tubes shows 0.00mm/year growth rate. In this case, the author concluded that the remaining life for these tubes will be the same as the remaining life of the system which are 8 years.

Remaining life analysis is about calculating the lifespan of each tube based on Eq.13. Based on table in appendix, the highest lifespan of the tubes is 34.54 years for tube number 124 and the lowest lifespan for the tubes is 0.00 for the failed tube. The average of the tube's lifespan is about 4 years from instant. This can be concluded that the average or estimated lifespan for the system is about 8 years which is equivalent to the design specification by the manufacturer.

4.2 Reliability of Steam Reformer Furnace

Based on the percentage of growth calculation, the author comes out with the percentage distribution for all the tubes which are 288 tubes. The purposed in developing the distribution graph is to study on the pattern of tube's growth after three (3) years operation. The graph distribution for percentage of growth in tube's internal diameter and outer diameter shows in Figure 11 and Figure 12.

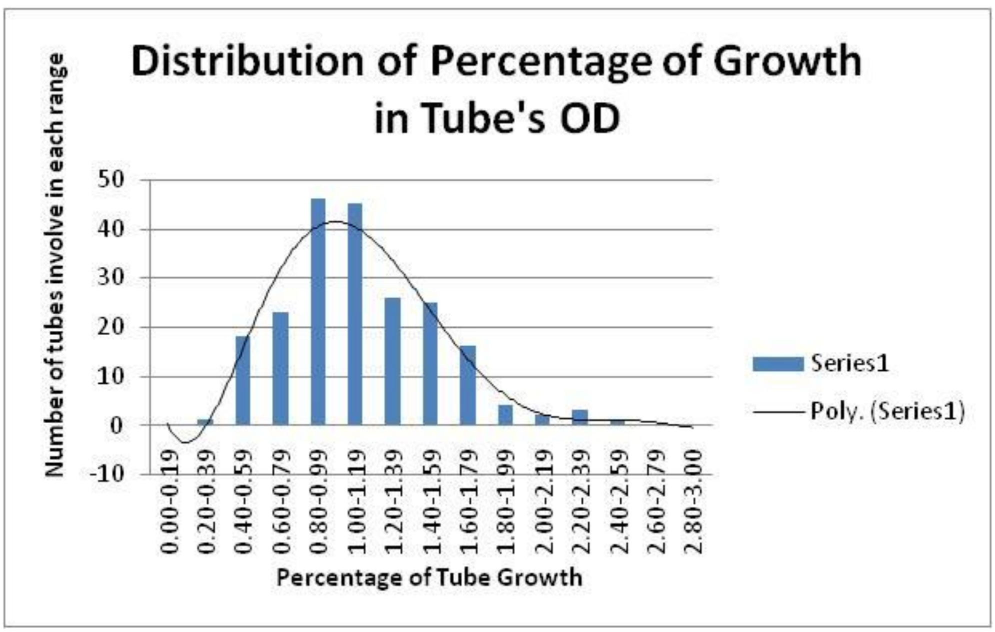

Figure 11: Distribution of Percentage of Growth in Tube's ID

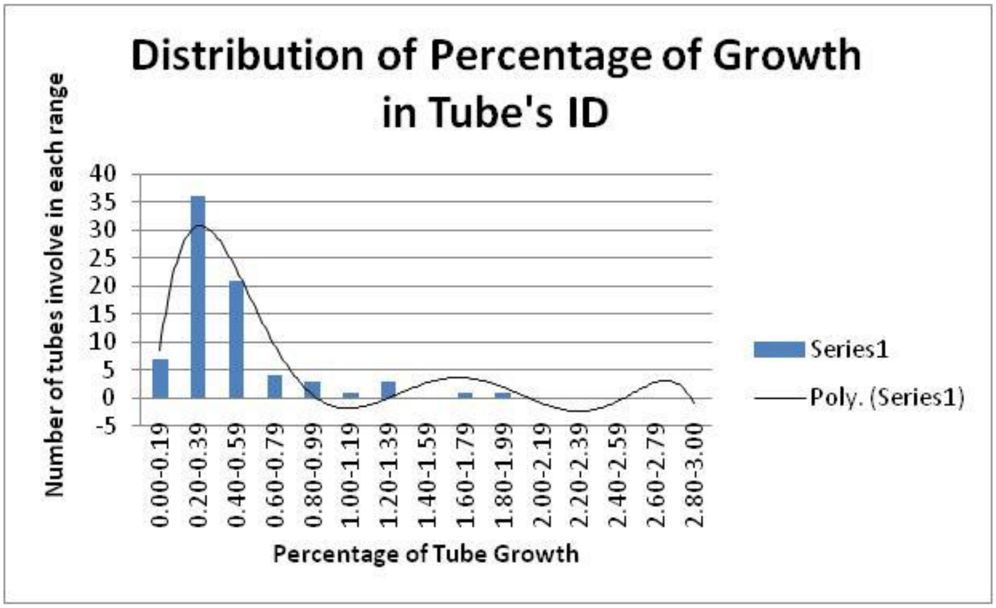

Figure 12: Distribution of Percentage of Growth in Tube's ID

The graph in Figure 11 and 12 shows a normal distribution graph. The normal distribution graph has a symmetrical shape as the mean of the growth rate at the maximum value of histogram. Based on graph in Figure 11 and Figure 12, the percentage of growth are more in tube's outer diameter as the heat transfer to the tube from outside to inside. Thus, the effect on tube growth and creep is affected more on outer wall other than inner wall. In three (3) years operation, the mean value for the tube growth is between 1.00 to 1.19 percent while the mean value of growth in inner wall is 0.59 to 0.65 percent.

Based on Eq.13, the percentage of growth can determined either the tube is passed or failed. The calculated percentage of growth is compared to tube's maximum percentage of growth. The tube's exceed the percentage of growth will consider failed and noted as "0" while the tube below maximum percentage of growth will consider pass and noted as "1". After all the tubes is assign on zero (0) and one (1) notation (Refer Appendix), The reliability is calculate as per Eq.2.

Based on the result on percentage of growth, the data counted shows 151 tubes is failed because it exceeds the maximum percentage number of growth. Thus, calculation for reliability is:

Reliability of the system, Q_s = 151/288 = 0.475694444

From the reliability of the system, probability of the steam reformer furnace to fail can be calculated as follow:

Probability of the system to fail, P_s = 1 – 0.475694444 = 0.524305556

Based on reliability general calculation, 47.6% of the system can survive after this three (3) years operation and 52.4% of the system exposed to failure. This result shows the probability is more that the reliability percentage, thus the equipment can be said not reliable to be operate at that instant or else the system need to be maintain or replace to a new steam reformer.

All the data will be transfer to the tube simulation and the pass tubes will shows green and the failed tube shows blue color. So, the reliability of the furnace will be calculated based on conditions that have been formatted in chapter 3. When all three (3) condition pass by the system, means the system still be reliable to be used in operation. Figure 21 shows the simulation results based on three (3) assign scenario explain in Chapter 3.

Scenario 1 10% out of 288

Q(k,n)	
P n	0.475694
Q n	0.524306
Q (k n-1)	
Q (k-1 n-1)	
k	151
n	288
result	0

Scenario 2 5% out of 144

P n	0.7260802
Q s	0.2739198
k (1)	71
k (2)	80
n	288
result (k1)	0
result (k2)	0
results	

Scenario 3 5 consecutive tubes failed

P i	1
q i	0
n r	114
k r	> 4
results	0

Figure 13: Reliability Analysis based on Scenarios

The result of the first condition is almost similar to the calculation of reliability based on data. But, the final result of the condition that the author want to analyze is the final result either the furnace system is pass or failed. From the simulation applied on datasheet and the assumption made based on scenario, it can be concluded that the system is failed and need to be maintain, or repaired or maybe replace because all three conditions agreed that the furnace system failed. By comparison from the data general calculation, the furnace system can also be considered as failed because the probability of the system to fail is higher than the reliability of the system. Thus, it can be concluded that both result is acceptable which the furnace system is failed from this data analysis.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In conclusion, this project is a research and reliability calculation model development based on reliability of furnace system (M.Zuo.1999). All the calculation and method applied in this study are taken from previous research on other system but the simulation develop in Microsoft Excel is applied to data from PETRONAS Ammonia Sdn Bhd. Based on the result obtained by general calculation or by condition or scenario assigned, the furnace system is consider failed. The furnace in this case needs to be service or replace to have more efficient function.

Other than that, the reliability of the furnace system needs to have a case study or expert opinion in order to know the predicted or estimated time for the tube to fail. Even the tube material is the same for each furnace or steam reformer but the pressure and temperature applied for each function is different cause the different in reliability for each furnace system.

In researching on reliability of the furnace system, the author recommends to have a field trip in plant in order to see in the real situation and understand deeply the system and operation of the steam reformer. This study on reliability of tubes in steam reformer can be expands on the other type of failure criteria. This report only focused on creep failure or tube’s growth, while the other failure is ignored. The study on other failure analysis will give more precise results in reliability of the steam reformer because of the defect of each tube’s might be different.

Other than that, in order to make this tube's spreadsheet model more user friendly, the coding system can be link into Visual Basic.net which can control the tube's cell and boxes, user input box, pop-up and other application to make the user easier. Other than that, the inspection table must have a fixed column to be filled by the user and other results will be automatically calculated.

This report also serves as a basis for a proper Reliability, Availability and Maintainability (RAM) model which can be constructed in the future and can be used for Universiti Teknologi PETRONAS (UTP) or for steam reformer evaluation in PETRONAS plants.

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APPENDICES

A1: Reformer and Tubing General Information

Unit ID Name/Numbers	Primary Steam Reformer-F3-1201
Service	Primary Steam Reformer
Reformer Manufacturer	Haldor Topsoe
Tube Manufacturer	Unknown
Tube Material	MicroAlloy
Flow Direction	Down
Internal Pressure at Top of tube	24 Kgf.cm2g
Target Tube skin Temperature	1020degC
Est. Number of Thermal Cycles	7
Tubes Put into Service	Feb-03 to Feb-06
Est. Operating Hours	Not Supplied
Tube Age at Inspection	5 to 8 years
Nominal Inner Diameter	103.0mm (4.055inch)
Nominal Outer Diameter	136.0mm (5.354 inch)
Nominal Tube Wall Thickness	Not Supplied
Tube Length	13m (42.6 ft)
Tube Inspection Location	95% of Tube's axial length
Tube Count Inspected	210

A2: Tube Growth Rate and Time to Failure

Row	Tube No.	Maximum Outer Diameter (mm)	Minimum Outer Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Calculated Maximum Growth Outer Diameter (mm)	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Maximum Internal Diameter (mm)	Minimum Internal Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Calculated Maximum Growth Outer	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Tube No.
1	1	136.8	135.1	1.26	1.31	137.78	0.27	3.68	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1
1	2	137.3	135.4	1.40	1.42	137.93	0.43	1.46	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2
1	3	137	135.9	0.81	0.77	137.05	0.33	0.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3
1	4	137.3	136.3	0.73	0.75	137.02	0.43	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4
1	5	138.1	136.7	1.02	0.98	137.33	0.70	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5
1	6	138.4	137.5	0.65	0.72	136.98	0.80	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6
1	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7
1	8	136.2	135.5	0.52	0.50	136.68	0.07	7.20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8
1	9	137.8	136.4	1.03	1.03	137.40	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9
1	10	136.6	135.6	0.74	0.76	137.03	0.20	2.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10
1	11	138.2	137.4	0.58	0.56	136.76	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11
1	12	137.2	136.4	0.59	0.55	136.75	0.40	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12
1	13	137.3	135.9	1.03	1.04	137.41	0.43	0.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13
1	14	138.1	136	1.54	1.59	138.16	0.70	0.09	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14
1	15	136.6	135.7	0.66	0.61	136.83	0.20	1.15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15
1	16	137.6	136.5	0.81	0.83	137.13	0.53	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16
1	17	136.3	135.4	0.66	0.68	136.92	0.10	6.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17
1	18	138.1	137.1	0.73	0.79	137.07	0.70	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18
1	19	137.5	135.7	1.33	1.33	137.81	0.50	0.62	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19
1	20	138.4	136.7	1.24	1.26	137.71	0.80	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20
1	21	137.4	136	1.03	1.02	137.39	0.47	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21
1	22	137.8	136.7	0.80	0.77	137.05	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22
1	23	138	136.7	0.95	0.95	137.29	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	23
1	24	137.6	136	1.18	1.17	137.59	0.53	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	24
1	25	137.3	135.1	1.63	1.64	138.23	0.43	2.15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25
1	26	138	136.1	1.40	1.37	137.86	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	26
1	27	138	136.4	1.17	1.19	137.62	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27
1	28	137.2	135.4	1.33	1.32	137.80	0.40	1.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28
1	29	137.5	136.1	1.03	1.00	137.36	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29
1	30	136.4	134.9	1.11	1.10	137.50	0.13	8.22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30
1	31	137	135.5	1.11	1.09	137.48	0.33	1.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	31
1	32	139.1	135.9	2.35	2.32	139.16	1.03	0.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32
1	33	138	135.4	1.92	1.93	138.62	0.67	0.94	N/A	N/A	N/A	N/A	N/A	N/A	N/A	33
1	34	138.9	135.6	2.43	2.42	139.29	0.97	0.40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34
1	35	138.7	136.6	1.54	1.54	138.09	0.90	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	35
1	36	138.3	135.9	1.77	1.73	138.35	0.77	0.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36
1	37	138.3	136.6	1.24	1.29	137.75	0.77	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37
1	38	138.5	136.8	1.24	1.23	137.67	0.83	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	38
1	39	137.6	134.9	2.00	1.98	138.69	0.53	2.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	39
1	40	137.7	136.4	0.95	0.89	137.21	0.57	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	40

Row	Tube No.	Maximum Outer Diameter (mm)	Minimum Outer Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Calculated Maximum Growth Outer Diameter (mm)	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Maximum Internal Diameter (mm)	Minimum Internal Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Calculated Maximum Growth Outer	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Tube No.
1	41	138.1	135.8	1.69	1.7	138.31	0.70	0.30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	41
1	42	136.5	135.2	0.96	0.93	137.26	0.17	4.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42
1	43	137.7	135.7	1.47	1.42	137.93	0.57	0.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43
1	44	137.5	135.1	1.78	1.74	138.37	0.50	1.73	N/A	N/A	N/A	N/A	N/A	N/A	N/A	44
1	45	137.7	136.6	0.81	0.76	137.03	0.57	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45
1	46	137.1	135.4	1.26	1.27	137.73	0.37	1.71	N/A	N/A	N/A	N/A	N/A	N/A	N/A	46
1	47	138.3	137	0.95	0.99	137.35	0.77	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	47
1	48	137.8	137	0.58	0.59	136.80	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	48
1	49	137.9	136.5	1.03	1.02	137.39	0.63	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	49
1	50	137.9	136.6	0.95	0.96	137.31	0.63	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	50
1	51	137.2	136.2	0.73	0.72	136.98	0.40	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	51
1	52	138.2	136.8	1.02	1.02	137.39	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	52
1	53	137.5	136.2	0.95	0.98	137.33	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	53
1	54	137.6	135.5	1.55	1.53	138.08	0.53	0.90	N/A	N/A	N/A	N/A	N/A	N/A	N/A	54
1	55	137.8	135.8	1.47	1.49	138.03	0.60	0.38	N/A	N/A	N/A	N/A	N/A	N/A	N/A	55
1	56	138.2	136.8	1.02	1.02	137.39	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	56
1	57	137.2	135.4	1.33	1.33	137.81	0.40	1.52	N/A	N/A	N/A	N/A	N/A	N/A	N/A	57
1	58	138.1	134.9	2.37	2.37	139.22	0.70	1.60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58
1	59	136.7	136.1	0.44	0.46	136.63	0.23	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	59
1	60	137.8	136.3	1.10	1.11	137.51	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	60
1	61	137.6	136.9	0.51	0.46	136.63	0.53	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	61
1	62	138	136.9	0.80	0.76	137.03	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	62
1	63	137.9	135.4	1.85	1.85	138.52	0.63	0.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	63
1	64	137	135.5	1.11	1.09	137.48	0.33	1.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	64
1	65	138.2	136.9	0.95	0.93	137.26	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	65
1	66	137.5	136	1.10	1.1	137.50	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66
1	67	138.6	137.6	0.73	0.69	136.94	0.87	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	67
1	68	137.5	136.4	0.81	0.78	137.06	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	68
1	69	136.9	135.2	1.26	1.23	137.67	0.30	2.58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	69
1	70	137.7	136.2	1.10	1.07	137.46	0.57	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	70
1	71	136	135.1	0.67	0.67	136.91	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	71
1	72	137.6	136	1.18	1.20	137.63	0.53	0.06	N/A	N/A	N/A	N/A	N/A	N/A	N/A	72
1	73	136.2	134.8	1.04	1.07	137.46	0.07	18.83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	73
1	74	136.8	135.5	0.96	1.00	137.36	0.27	2.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	74
1	75	137.8	137	0.58	0.54	136.73	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	75
1	76	137.3	135.6	1.25	1.28	137.74	0.43	1.02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	76
1	77	137.4	136.5	0.66	0.66	136.90	0.47	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	77
1	78	136.9	135.8	0.81	0.87	137.18	0.30	0.94	N/A	N/A	N/A	N/A	N/A	N/A	N/A	78
1	79	137.1	135.3	1.33	1.39	137.89	0.37	2.16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	79
1	80	136.9	135	1.41	1.40	137.90	0.30	3.35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	80
1	81	135.9	135.2	0.52	0.54	136.73	-0.03	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	81
1	82	136.3	135.5	0.59	0.61	136.83	0.10	5.30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	82
1	83	137.7	135.8	1.40	1.39	137.89	0.57	0.34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	83
1	84	137	135.9	0.81	0.84	137.14	0.33	0.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	84
1	85	137.4	136.2	0.88	0.92	137.25	0.47	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	85

Row	Tube No.	Maximum Outer Diameter (mm)	Minimum Outer Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Calculated Maximum Growth Outer Diameter (mm)	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Maximum Internal Diameter (mm)	Minimum Internal Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Calculated Maximum Growth Outer	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Tube No.
1	86	137.8	137	0.58	0.57	136.78	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	86
1	87	137.6	136.2	1.03	1.04	137.41	0.53	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	87
1	88	137.7	135.8	1.40	1.42	137.93	0.57	0.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	88
1	89	137.5	136.2	0.95	0.93	137.26	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	89
1	90	136.9	135.9	0.74	0.76	137.03	0.30	0.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	90
1	91	136.8	135.4	1.03	0.96	137.31	0.27	1.90	N/A	N/A	N/A	N/A	N/A	N/A	N/A	91
1	92	137.4	135.9	1.10	1.10	137.50	0.47	0.21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	92
1	93	138.1	136.6	1.10	1.11	137.51	0.70	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	93
1	94	137.7	136.1	1.18	1.15	137.56	0.57	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	94
1	95	137.5	136.3	0.88	0.91	137.24	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	95
1	96	137.1	135.8	0.96	0.99	137.35	0.37	0.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	96
1	97	137.6	135.7	1.40	1.44	137.96	0.53	0.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	97
1	98	136.3	134.9	1.04	1.07	137.46	0.10	11.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	98
1	99	136	135.2	0.59	0.57	136.78	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	99
1	100	137.3	135.8	1.10	1.07	137.46	0.43	0.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100
1	101	137.7	136.4	0.95	0.94	137.28	0.57	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	101
1	102	137.5	136.1	1.03	1.05	137.43	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102
1	103	137.7	135.7	1.47	1.49	138.03	0.57	0.58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103
1	104	136.1	135.4	0.52	0.54	136.73	0.03	19.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	104
1	105	138.6	136.9	1.24	1.26	137.71	0.87	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	105
1	106	137.6	135.7	1.40	1.45	137.97	0.53	0.70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	106
1	107	136.3	134.7	1.19	1.17	137.59	0.10	12.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	107
1	108	137.2	135.9	0.96	0.98	137.33	0.40	0.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	108
1	109	136.9	135	1.41	1.40	137.90	0.30	3.35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	109
1	110	137.2	135.2	1.48	1.45	137.97	0.40	1.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	110
1	111	137.5	136.2	0.95	0.92	137.25	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	111
1	112	137.4	135.9	1.10	1.15	137.56	0.47	0.35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	112
1	113	136.5	134.8	1.26	1.26	137.71	0.17	7.28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	113
1	114	137.3	135.9	1.03	1.05	137.43	0.43	0.30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	114
1	115	137.3	135.8	1.10	1.12	137.52	0.43	0.52	N/A	N/A	N/A	N/A	N/A	N/A	N/A	115
1	116	136.9	135.2	1.26	1.25	137.70	0.30	2.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	116
1	117	135.7	134.4	0.97	0.94	137.28	-0.10	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	117
1	118	136.2	135.3	0.67	0.67	136.91	0.07	10.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	118
1	119	137.4	136	1.03	1.04	137.41	0.47	0.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	119
1	120	136.9	135.8	0.81	0.77	137.05	0.30	0.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	120
1	121	136.7	135.4	0.96	0.95	137.29	0.23	2.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	121
1	122	137.1	135.3	1.33	1.36	137.85	0.37	2.04	N/A	N/A	N/A	N/A	N/A	N/A	N/A	122
1	123	137.2	135.4	1.33	1.38	137.88	0.40	1.69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	123
1	124	136.1	134.8	0.96	0.92	137.25	0.03	34.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	124
1	125	137.5	135.1	1.78	1.78	138.42	0.50	1.84	N/A	N/A	N/A	N/A	N/A	N/A	N/A	125

Row	Tube No.	Maximum Outer Diameter (mm)	Minimum Outer Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Calculated Maximum Growth Outer Diameter (mm)	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Maximum Internal Diameter (mm)	Minimum Internal Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Calculated Maximum Growth Outer	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Tube No.
1	126	137.3	136.2	0.81	0.81	137.10	0.43	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	126
1	127	137.1	136.3	0.59	0.54	136.73	0.37	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	127
1	128	137.2	135	1.63	1.61	138.19	0.40	2.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	128
1	129	137.3	136.1	0.88	0.89	137.21	0.43	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	129
1	130	137	136	0.74	0.77	137.05	0.33	0.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	130
1	131	137.4	135.5	1.40	1.34	137.82	0.47	0.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	131
1	132	137.1	135.8	0.96	0.94	137.28	0.37	0.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	132
1	133	137.6	135.5	1.55	1.5	138.04	0.53	0.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	133
1	134	136.7	135.4	0.96	0.92	137.25	0.23	2.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	134
1	135	137.3	135.4	1.40	1.43	137.94	0.43	1.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	135
1	136	138.3	136.2	1.54	1.52	138.07	0.77	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	136
1	137	138.1	135.9	1.62	1.63	138.22	0.70	0.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	137
1	138	137.1	136.1	0.73	0.66	136.90	0.37	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	138
1	139	136.2	135.7	0.37	0.42	136.57	0.07	5.57	N/A	N/A	N/A	N/A	N/A	N/A	N/A	139
1	140	137.5	136.6	0.66	0.71	136.97	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	140
1	141	136.4	135.8	0.44	0.43	136.58	0.13	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A	141
1	142	137.8	136.4	1.03	0.97	137.32	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	142
1	143	137.8	137	0.58	0.6	136.82	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	143
1	144	138	135.7	1.69	1.7	138.31	0.67	0.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	144
2	145	138	136.2	1.32	1.27	137.73	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	145
2	146	138.5	135.9	1.91	1.88	138.56	0.83	0.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	146
2	147	138.3	135.9	1.77	1.79	138.43	0.77	0.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	147
2	148	137.4	136.1	0.96	0.96	137.31	0.47	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	148
2	149	138.6	136.7	1.39	1.42	137.93	0.87	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	149
2	150	137.7	137	0.51	0.56	136.76	0.57	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	150
2	151	137.8	136.7	0.80	0.83	137.13	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	151
2	152	138.7	135.6	2.29	2.30	139.13	0.90	0.48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	152
2	153	137.9	135.5	1.77	1.76	138.39	0.63	0.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	153
2	154	138.5	136.5	1.47	1.45	137.97	0.83	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	154
2	155	138.2	136.4	1.32	1.26	137.71	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	155
2	156	138.2	135.8	1.77	1.73	138.35	0.73	0.21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	156
2	157	138.1	136.3	1.32	1.31	137.78	0.70	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	157
2	158	138.3	136.5	1.32	1.34	137.82	0.77	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	158
2	159	138	136.8	0.88	0.84	137.14	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	159
2	160	138.6	137.5	0.80	0.75	137.02	0.87	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	160
2	161	137.6	136.2	1.03	1.01	137.37	0.53	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	161
2	162	138.7	137	1.24	1.18	137.60	0.90	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	162
2	163	138	236.8	-41.72	0.89	137.21	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	163
2	164	138.2	137.1	0.80	0.84	137.14	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	164
2	165	137.5	136.5	0.73	0.75	137.02	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	165
2	166	137.5	136.1	1.03	1.05	137.43	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	166
2	167	138.4	137.4	0.73	0.73	136.99	0.80	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	167
2	168	137.3	136	0.96	0.99	137.35	0.43	0.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	168
2	169	137.3	135.1	1.63	1.64	138.23	0.43	2.15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	169
2	170	137	136.1	0.66	0.65	136.88	0.33	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	170

Row	Tube No.	Maximum Outer Diameter (mm)	Minimum Outer Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Calculated Maximum Growth Outer Diameter (mm)	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Maximum Internal Diameter (mm)	Minimum Internal Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Calculated Maximum Growth Outer	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Tube No.
2	171	137.5	136.2	0.95	0.94	137.28	0.50	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	171
2	172	137.6	136.2	1.03	1.02	137.39	0.53	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	172
2	173	138.1	136.6	1.10	1.09	137.48	0.70	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	173
2	174	138.6	137.1	1.09	1.04	137.41	0.87	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	174
2	175	137.7	135.8	1.40	1.35	137.84	0.57	0.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	175
2	176	138	135.9	1.55	1.50	138.04	0.67	0.06	N/A	N/A	N/A	N/A	N/A	N/A	N/A	176
2	177	138.1	136.5	1.17	1.15	137.56	0.70	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	177
2	178	137.8	137.2	0.44	0.44	136.60	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	178
2	179	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	179
2	180	138.2	135.7	1.84	1.9	138.58	0.73	0.52	N/A	N/A	N/A	N/A	N/A	N/A	N/A	180
2	181	139	138	0.72	0.73	136.99	1.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	181
2	182	137.8	136.2	1.17	1.18	137.60	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	182
2	183	137.6	136	1.18	1.16	137.58	0.53	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	183
2	184	138.1	135.9	1.62	1.65	138.24	0.70	0.21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	184
2	185	138.7	137.5	0.87	0.90	137.22	0.90	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	185
2	186	138.8	137.9	0.65	0.65	136.88	0.93	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	186
2	187	137.5	135.7	1.33	1.31	137.78	0.50	0.56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	187
2	188	137.9	136	1.40	1.34	137.82	0.63	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	188
2	189	138.6	136.3	1.69	1.71	138.33	0.87	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	189
2	190	136.7	135.7	0.74	0.73	136.99	0.23	1.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	190
2	191	138	136.2	1.32	1.27	137.73	0.67	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	191
2	192	137	135.7	0.96	0.93	137.26	0.33	0.79	N/A	N/A	N/A	N/A	N/A	N/A	N/A	192
2	193	136.9	135.1	1.33	1.33	137.81	0.30	3.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	193
2	194	138.2	136.2	1.47	1.49	138.03	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	194
2	195	137.8	136.7	0.80	0.81	137.10	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	195
2	196	138.1	136.8	0.95	0.96	137.31	0.70	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	196
2	197	137.4	136.1	0.96	0.95	137.29	0.47	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	197
2	198	138.2	136.4	1.32	1.31	137.78	0.73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	198
2	199	138.2	135.8	1.77	1.77	138.41	0.73	0.28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	199
2	200	136.9	135.8	0.81	0.79	137.07	0.30	0.58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	200
2	201	138.5	135.7	2.06	2.04	138.77	0.83	0.33	104.9	102	1.84	2.78	105.86	0.63	1.52	201
2	202	138.3	136.3	1.47	1.47	138.00	0.77	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	202
2	203	138.3	136.6	1.24	1.28	137.74	0.77	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	203
2	204	137.2	135.7	1.11	1.11	137.51	0.40	0.77	103.8	102.4	1.37	1.36	104.40	0.27	2.25	204
2	205	137.7	136.2	1.10	1.05	137.43	0.57	0.00	103	102	0.98	0.98	104.01	0.00	N/A	205
2	206	138	136.4	1.17	1.16	137.58	0.67	0.00	104.8	103.5	1.26	1.26	104.30	0.60	0.00	206
2	207	137.7	136.5	0.88	0.86	137.17	0.57	0.00	103.4	103	0.39	0.4	103.41	0.13	0.09	207
2	208	137.5	135.9	1.18	1.16	137.58	0.50	0.16	103.3	102.8	0.49	0.49	103.50	0.10	2.05	208
2	209	137.8	136.2	1.17	1.21	137.65	0.60	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	209
2	210	137.8	136.6	0.88	0.83	137.13	0.60	0.00	103	102.2	0.78	0.82	103.84	0.00	N/A	210
2	211	137.3	136.6	0.51	0.52	136.71	0.43	0.00	103.6	103.1	0.48	0.49	103.50	0.20	0.00	211
2	212	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.1	102.7	0.39	0.39	103.40	0.03	9.05	212
2	213	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.9	102.4	0.49	0.47	103.48	-0.03	0.00	213
2	214	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.4	0.39	0.39	103.40	-0.07	0.00	214
2	215	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.3	103.1	0.19	0.21	103.22	0.10	0.00	215

Row	Tube No.	Maximum Outer Diameter (mm)	Minimum Outer Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Calculated Maximum Growth Outer Diameter (mm)	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Maximum Internal Diameter (mm)	Minimum Internal Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Calculated Maximum Growth Outer	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Tube No.
2	216	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	216
2	217	138.1	136.8	0.95	0.91	137.24	0.70	0.00	104.5	102.8	1.65	1.62	104.67	0.50	0.34	217
2	218	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.8	103.4	0.39	0.33	103.34	0.27	0.00	218
2	219	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.6	102.4	0.20	0.16	103.16	-0.13	0.00	219
2	220	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.6	0.39	0.37	103.38	0.00	N/A	220
2	221	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.9	102.7	0.19	0.2	103.21	-0.03	0.00	221
2	222	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.2	102.9	0.29	0.32	103.33	0.07	1.94	222
2	223	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.4	102.8	0.58	0.58	103.60	0.13	1.48	223
2	224	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.5	103.1	0.39	0.34	103.35	0.17	0.00	224
2	225	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.2	102.7	0.49	0.48	103.49	0.07	4.42	225
2	226	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.8	103.3	0.48	0.44	103.45	0.27	0.00	226
2	227	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.4	0.59	0.58	103.60	0.00	N/A	227
2	228	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.3	102.9	0.39	0.4	103.41	0.10	1.12	228
2	229	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102.5	0.20	0.2	103.21	-0.10	0.00	229
2	230	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.4	102.1	0.29	0.26	103.27	-0.20	0.00	230
2	231	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102.4	0.29	0.33	103.34	-0.10	0.00	231
2	232	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.4	102.1	0.29	0.3	103.31	-0.20	0.00	232
2	233	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.4	0.39	0.35	103.36	-0.07	0.00	233
2	234	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.4	0.39	0.42	103.43	-0.07	0.00	234
2	235	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102.2	0.49	0.48	103.49	-0.10	0.00	235
2	236	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.4	102	0.39	0.36	103.37	-0.20	0.00	236
2	237	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.4	102.1	0.29	0.29	103.30	-0.20	0.00	237
2	238	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.1	101.9	0.20	0.19	103.20	-0.30	0.00	238
2	239	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.6	102.4	0.20	0.14	103.14	-0.13	0.00	239
2	240	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.5	103.1	0.39	0.41	103.42	0.17	0.00	240
2	241	N/A	N/A	N/A	N/A	N/A	N/A	N/A	104.7	103.4	1.26	1.23	104.27	0.57	0.00	241
2	242	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.3	102.8	0.49	0.48	103.49	0.10	1.94	242
2	243	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.8	0.19	0.15	103.15	0.00	N/A	243
2	244	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.2	102.8	0.39	0.37	103.38	0.07	2.72	244
2	245	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.8	0.19	0.17	103.18	0.00	N/A	245
2	246	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102	0.69	0.62	103.64	-0.10	0.00	246
2	247	N/A	N/A	N/A	N/A	N/A	N/A	N/A	104	103	0.97	0.93	103.96	0.33	0.00	247
2	248	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.5	102.3	0.20	0.26	103.27	-0.17	0.00	248
2	249	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.2	102.8	0.39	0.42	103.43	0.07	3.49	249
2	250	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.9	102.4	0.49	0.51	103.53	-0.03	0.00	250

Row	Tube No.	Maximum Outer Diameter (mm)	Minimum Outer Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Calculated Maximum Growth Outer Diameter (mm)	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Maximum Internal Diameter (mm)	Minimum Internal Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Calculated Maximum Growth Outer	Tube Growth Rate (mm/yrs)	Time to Failure (yrs)	Tube No.
2	251	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.3	0.49	0.5	103.52	-0.07	0.00	251
2	252	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.5	0.49	0.44	103.45	0.00	N/A	252
2	253	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.6	0.19	0.19	103.20	-0.07	0.00	253
2	254	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.9	102.6	0.29	0.28	103.29	-0.03	0.00	254
2	255	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	255
2	256	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.5	102	0.49	0.49	103.50	-0.17	0.00	256
2	257	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.7	0.29	0.27	103.28	0.00	N/A	257
2	258	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.1	102	1.08	1.02	104.05	0.03	28.52	258
2	259	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.3	0.49	0.46	103.47	-0.07	0.00	259
2	260	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.6	102	0.59	0.65	103.67	-0.13	0.00	260
2	261	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.5	102.3	0.20	0.24	103.25	-0.17	0.00	261
2	262	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.3	0.49	0.44	103.45	-0.07	0.00	262
2	263	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.9	102.5	0.39	0.39	103.40	-0.03	0.00	263
2	264	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102.3	0.39	0.47	103.48	-0.10	0.00	264
2	265	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.5	0.49	0.44	103.45	0.00	N/A	265
2	266	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.9	102.4	0.49	0.46	103.47	-0.03	0.00	266
2	267	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102.3	0.39	0.36	103.37	-0.10	0.00	267
2	268	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.6	102.4	0.20	0.2	103.21	-0.13	0.00	268
2	269	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.8	0.19	0.26	103.27	0.00	N/A	269
2	270	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103	102.8	0.19	0.25	103.26	0.00	N/A	270
2	271	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102.3	0.39	0.41	103.42	-0.10	0.00	271
2	272	N/A	N/A	N/A	N/A	N/A	N/A	N/A	103.2	102.3	0.88	0.97	104.00	0.07	11.99	272
2	273	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	273
2	274	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.5	102.1	0.39	0.44	103.45	-0.17	0.00	274
2	275	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102	0.78	0.74	103.76	-0.07	0.00	275
2	276	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	276
2	277	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	277
2	278	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	278
2	279	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102.4	0.39	0.44	103.45	-0.07	0.00	279
2	280	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.5	102	0.49	0.44	103.45	-0.17	0.00	280
2	281	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	281
2	282	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	282
2	283	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.8	102	0.78	0.73	103.75	-0.07	0.00	283
2	284	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.6	102.4	0.20	0.25	103.26	-0.13	0.00	284
2	285	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.4	102.2	0.20	0.21	103.22	-0.20	0.00	285
2	286	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.3	102	0.29	0.27	103.28	-0.23	0.00	286
2	287	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.4	102.1	0.29	0.25	103.26	-0.20	0.00	287
2	288	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.7	102.2	0.49	0.47	103.48	-0.10	0.00	288

A3: Inspection Result Analysis

Row	Tube No.	Maximum Outer Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Outer Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Pass/Fail	Maximum Internal Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Internal Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Pass/Fail	Tube Pass/Fail	Tube No.
1	1	136.8	5300	135.1	10634	1.26	1.31	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1
1	2	137.3	3332	135.4	8854	1.40	1.42	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	2
1	3	137	3355	135.9	6630	0.81	0.77	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	3
1	4	137.3	12594	136.3	8711	0.73	0.75	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	4
1	5	138.1	3238	136.7	988	1.02	0.98	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	5
1	6	138.4	6031	137.5	7927	0.65	0.72	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	6
1	7	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	7
1	8	136.2	3951	135.5	1877	0.52	0.50	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	8
1	9	137.8	179	136.4	1915	1.03	1.03	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	9
1	10	136.6	5761	135.6	8231	0.74	0.76	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	10
1	11	138.2	2252	137.4	4263	0.58	0.56	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	11
1	12	137.2	2965	136.4	5332	0.59	0.55	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	12
1	13	137.3	3288	135.9	7739	1.03	1.04	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	13
1	14	138.1	3210	136	6285	1.54	1.59	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	14
1	15	136.6	8590	135.7	10914	0.66	0.61	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	15
1	16	137.6	5816	136.5	8283	0.81	0.83	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	16
1	17	136.3	1206	135.4	3554	0.66	0.68	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	17
1	18	138.1	5946	137.1	7903	0.73	0.79	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	18
1	19	137.5	3385	135.7	10167	1.33	1.33	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	19
1	20	138.4	12717	136.7	8537	1.24	1.26	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	20
1	21	137.4	640	136	4798	1.03	1.02	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	21
1	22	137.8	3222	136.7	257	0.80	0.77	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	22
1	23	138	3204	136.7	251	0.95	0.95	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	23
1	24	137.6	3383	136	6630	1.18	1.17	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	24
1	25	137.3	1923	135.1	7856	1.63	1.64	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	25
1	26	138	2255	136.1	7800	1.40	1.37	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	26
1	27	138	2349	136.4	7324	1.17	1.19	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	27
1	28	137.2	4129	135.4	12047	1.33	1.32	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	28
1	29	137.5	3408	136.1	7275	1.03	1.00	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	29
1	30	136.4	3312	134.9	7686	1.11	1.10	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	30
1	31	137	12751	135.5	9532	1.11	1.09	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	31
1	32	139.1	12777	135.9	7025	2.35	2.32	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	32
1	33	138	3423	135.4	7548	1.92	1.93	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	33
1	34	138.9	12429	135.6	5888	2.43	2.42	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	34
1	35	138.7	5348	136.6	9708	1.54	1.54	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	35
1	36	138.3	3033	135.9	9472	1.77	1.73	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	36
1	37	138.3	3216	136.6	7644	1.24	1.29	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	37
1	38	138.5	3194	136.8	409	1.24	1.23	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	38
1	39	137.6	2171	134.9	7629	2.00	1.98	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	39
1	40	137.7	1461	136.4	4715	0.95	0.89	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	40
1	41	138.1	3263	135.8	7756	1.69	1.7	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	41
1	42	136.5	8135	135.2	5058	0.96	0.93	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	42
1	43	137.7	2130	135.7	8630	1.47	1.42	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	43
1	44	137.5	3505	135.1	7950	1.78	1.74	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	44
1	45	137.7	3406	136.6	5515	0.81	0.76	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	45

Row	Tube No.	Maximum Outer Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Outer Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Pass/Fail	Maximum Internal Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Internal Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Pass/Fail	Tube Pass/Fail	Tube No.
1	46	137.1	1624	135.4	9743	1.26	1.27	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	46
1	47	138.3	3017	137	203	0.95	0.99	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	47
1	48	137.8	5963	137	8044	0.58	0.59	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	48
1	49	137.9	2338	136.5	5311	1.03	1.02	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	49
1	50	137.9	5792	136.6	9963	0.95	0.96	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	50
1	51	137.2	9186	136.2	5985	0.73	0.72	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	51
1	52	138.2	3138	136.8	513	1.02	1.02	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	52
1	53	137.5	2104	136.2	5048	0.95	0.98	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	53
1	54	137.6	3309	135.5	12180	1.55	1.53	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	54
1	55	137.8	3175	135.8	7242	1.47	1.49	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	55
1	56	138.2	2877	136.8	625	1.02	1.02	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	56
1	57	137.2	3492	135.4	7853	1.33	1.33	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	57
1	58	138.1	3146	134.9	7386	2.37	2.37	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	58
1	59	136.7	8912	136.1	11971	0.44	0.46	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	59
1	60	137.8	3333	136.3	7663	1.10	1.11	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	60
1	61	137.6	2616	136.9	5181	0.51	0.46	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	61
1	62	138	3108	136.9	1129	0.80	0.76	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	62
1	63	137.9	3039	135.4	7686	1.85	1.85	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	63
1	64	137	258	135.5	3667	1.11	1.09	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	64
1	65	138.2	2565	136.9	679	0.95	0.93	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	65
1	66	137.5	3274	136	7706	1.10	1.1	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	66
1	67	138.6	5048	137.6	2743	0.73	0.69	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	67
1	68	137.5	4163	136.4	6914	0.81	0.78	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	68
1	69	136.9	3670	135.2	7883	1.26	1.23	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	69
1	70	137.7	3382	136.2	7824	1.10	1.07	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	70
1	71	136	12700	135.1	8395	0.67	0.67	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	71
1	72	137.6	3297	136	7852	1.18	1.2	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	72
1	73	136.2	5804	134.8	8750	1.04	1.07	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	73
1	74	136.8	10761	135.5	8734	0.96	1	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	74
1	75	137.8	2587	137	108	0.58	0.54	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	75
1	76	137.3	2298	135.6	7644	1.25	1.28	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	76
1	77	137.4	7850	136.5	5141	0.66	0.66	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	77
1	78	136.9	8084	135.8	12652	0.81	0.87	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	78
1	79	137.1	3302	135.3	7552	1.33	1.39	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	79
1	80	136.9	3268	135	7719	1.41	1.4	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	80
1	81	135.9	11450	135.2	9503	0.52	0.54	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	81
1	82	136.3	11566	135.5	8331	0.59	0.61	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	82
1	83	137.7	5736	135.8	9876	1.40	1.39	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	83
1	84	137	3038	135.9	7251	0.81	0.84	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	84
1	85	137.4	3310	136.2	1128	0.88	0.92	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	85
1	86	137.8	116	137	2252	0.58	0.57	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	86
1	87	137.6	6099	136.2	1935	1.03	1.04	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	87
1	88	137.7	3244	135.8	7689	1.40	1.42	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	88
1	89	137.5	8336	136.2	11222	0.95	0.93	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	89
1	90	136.9	3857	135.9	7839	0.74	0.76	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	90

Row	Tube No.	Maximum Outer Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Outer Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Pass/Fail	Maximum Internal Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Internal Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Pass/Fail	Tube Pass/Fail	Tube No.
1	91	136.8	8058	135.4	10166	1.03	0.96	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	91
1	92	137.4	2573	135.9	5958	1.10	1.1	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	92
1	93	138.1	3409	136.6	7612	1.10	1.11	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	93
1	94	137.7	3051	136.1	4645	1.18	1.15	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	94
1	95	137.5	8071	136.3	12157	0.88	0.91	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	95
1	96	137.1	3583	135.8	7650	0.96	0.99	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	96
1	97	137.6	2442	135.7	6627	1.40	1.44	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	97
1	98	136.3	7190	134.9	3131	1.04	1.07	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	98
1	99	136	526	135.2	4033	0.59	0.57	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	99
1	100	137.3	2702	135.8	6096	1.10	1.07	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	100
1	101	137.7	3189	136.4	1952	0.95	0.94	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	101
1	102	137.5	3248	136.1	7646	1.03	1.05	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	102
1	103	137.7	2998	135.7	7691	1.47	1.49	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	103
1	104	136.1	12778	135.4	8474	0.52	0.54	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	104
1	105	138.6	5344	136.9	8124	1.24	1.26	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	105
1	106	137.6	3265	135.7	7615	1.40	1.45	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	106
1	107	136.3	5743	134.7	8902	1.19	1.17	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	107
1	108	137.2	12652	135.9	10121	0.96	0.98	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	108
1	109	136.9	3381	135	7424	1.41	1.4	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	109
1	110	137.2	3154	135.2	7228	1.48	1.45	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	110
1	111	137.5	3413	136.2	7752	0.95	0.92	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	111
1	112	137.4	3233	135.9	7555	1.10	1.15	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	112
1	113	136.5	12734	134.8	8183	1.26	1.26	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	113
1	114	137.3	3496	135.9	10297	1.03	1.05	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	114
1	115	137.3	3161	135.8	9518	1.10	1.12	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	115
1	116	136.9	3587	135.2	7769	1.26	1.25	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	116
1	117	135.7	6967	134.4	3442	0.97	0.94	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	117
1	118	136.2	5150	135.3	2076	0.67	0.67	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	118
1	119	137.4	7703	136	3623	1.03	1.04	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	119
1	120	136.9	3520	135.8	6554	0.81	0.77	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	120
1	121	136.7	12113	135.4	8322	0.96	0.95	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	121
1	122	137.1	3462	135.3	7983	1.33	1.36	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	122
1	123	137.2	3468	135.4	7789	1.33	1.38	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	123
1	124	136.1	12119	134.8	8482	0.96	0.92	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	124
1	125	137.5	2410	135.1	8279	1.78	1.78	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	125
1	126	137.3	12130	136.2	8759	0.81	0.81	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	126
1	127	137.1	5059	136.3	3459	0.59	0.54	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	127
1	128	137.2	3341	135	7650	1.63	1.61	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	128
1	129	137.3	2981	136.1	6899	0.88	0.89	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	129
1	130	137	4952	136	7404	0.74	0.77	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	130
1	131	137.4	3441	135.5	7866	1.40	1.34	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	131
1	132	137.1	12815	135.8	9195	0.96	0.94	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	132
1	133	137.6	2169	135.5	7711	1.55	1.5	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	133
1	134	136.7	11701	135.4	8312	0.96	0.92	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	134
1	135	137.3	11168	135.4	8803	1.40	1.43	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	135

Row	Tube No.	Maximum Outer Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Outer Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Pass/Fail	Maximum Internal Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Internal Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Pass/Fail		Tube Pass/Fail	Tube No.
1	136	138.3	3154	136.2	5752	1.54	1.52	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	136
1	137	138.1	3398	135.9	7148	1.62	1.63	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	137
1	138	137.1	4183	136.1	5835	0.73	0.66	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	138
1	139	136.2	8531	135.7	10859	0.37	0.42	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	139
1	140	137.5	3574	136.6	7894	0.66	0.71	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	140
1	141	136.4	12815	135.8	9769	0.44	0.43	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	141
1	142	137.8	3219	136.4	6377	1.03	0.97	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	142
1	143	137.8	3552	137	7631	0.58	0.6	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	143
1	144	138	1347	135.7	7820	1.69	1.7	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	144
2	145	138	9043	136.2	7325	1.32	1.27	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	145
2	146	138.5	10843	135.9	9996	1.91	1.88	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	146
2	147	138.3	3707	135.9	10423	1.77	1.79	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	147
2	148	137.4	12400	136.1	9978	0.96	0.96	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	148
2	149	138.6	3383	136.7	7328	1.39	1.42	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	149
2	150	137.7	3986	137	7341	0.51	0.56	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	150
2	151	137.8	3456	136.7	794	0.80	0.83	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	151
2	152	138.7	3508	135.6	9449	2.29	2.3	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	152
2	153	137.9	3583	135.5	11288	1.77	1.76	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	153
2	154	138.5	3458	136.5	7710	1.47	1.45	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	154
2	155	138.2	3859	136.4	7751	1.32	1.26	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	155
2	156	138.2	2512	135.8	7722	1.77	1.73	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	156
2	157	138.1	2582	136.3	7268	1.32	1.31	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	157
2	158	138.3	3361	136.5	6665	1.32	1.34	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	158
2	159	138	3557	136.8	7618	0.88	0.84	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	159
2	160	138.6	12792	137.5	7475	0.80	0.75	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	160
2	161	137.6	3650	136.2	7063	1.03	1.01	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	161
2	162	138.7	3242	137	163	1.24	1.18	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	162
2	163	138	2937	236.8	267	-41.72	0.89	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	163
2	164	138.2	3317	137.1	428	0.80	0.84	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	164
2	165	137.5	5280	136.5	7803	0.73	0.75	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	165
2	166	137.5	8137	136.1	11306	1.03	1.05	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	166
2	167	138.4	3446	137.4	148	0.73	0.73	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	167
2	168	137.3	11613	136	8247	0.96	0.99	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	168
2	169	137.3	7886	135.1	11812	1.63	1.64	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	169
2	170	137	12594	136.1	8330	0.66	0.65	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	170
2	171	137.5	12737	136.2	8250	0.95	0.94	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	171
2	172	137.6	8059	136.2	12522	1.03	1.02	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	172
2	173	138.1	3458	136.6	7102	1.10	1.09	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	173
2	174	138.6	3321	137.1	33	1.09	1.04	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	174
2	175	137.7	8497	135.8	12273	1.40	1.35	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	175
2	176	138	3347	135.9	7631	1.55	1.5	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	176
2	177	138.1	10214	136.5	8694	1.17	1.15	0	N/A	N/A	N/A	N/A	N/A	N/A	1		0	177
2	178	137.8	5868	137.2	8900	0.44	0.44	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	178
2	179	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	179
2	180	138.2	2645	135.7	7799	1.84	1.9	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	180

Row	Tube No.	Maximum Outer Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Outer Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Pass/Fail	Maximum Internal Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Internal Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Pass/Fail	Tube Pass/Fail	Tube No.
2	181	139	1638	138	269	0.72	0.73	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	181
2	182	137.8	3731	136.2	7910	1.17	1.18	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	182
2	183	137.6	3540	136	7965	1.18	1.16	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	183
2	184	138.1	3716	135.9	7884	1.62	1.65	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	184
2	185	138.7	3451	137.5	466	0.87	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	185
2	186	138.8	5551	137.9	2441	0.65	0.65	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	186
2	187	137.5	3563	135.7	7896	1.33	1.31	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	187
2	188	137.9	3735	136	7664	1.40	1.34	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	188
2	189	138.6	3489	136.3	7610	1.69	1.71	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	189
2	190	136.7	12706	135.7	11960	0.74	0.73	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	190
2	191	138	3596	136.2	7422	1.32	1.27	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	191
2	192	137	3441	135.7	7798	0.96	0.93	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	192
2	193	136.9	8139	135.1	11962	1.33	1.33	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	193
2	194	138.2	2426	136.2	7309	1.47	1.49	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	194
2	195	137.8	6520	136.7	2793	0.80	0.81	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	195
2	196	138.1	3109	136.8	7291	0.95	0.96	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	196
2	197	137.4	12733	136.1	8042	0.96	0.95	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	197
2	198	138.2	3270	136.4	6929	1.32	1.31	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	198
2	199	138.2	3121	135.8	8802	1.77	1.77	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	199
2	200	136.9	11426	135.8	7836	0.81	0.79	0	N/A	N/A	N/A	N/A	N/A	N/A	1	0	200
2	201	138.5	12745	135.7	7390	2.06	2.04	0	104.9	133373	102	8141	2.84	2.78	0	0	201
2	202	138.3	9854	136.3	4360	1.47	1.47	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	202
2	203	138.3	10518	136.6	4839	1.24	1.28	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	203
2	204	137.2	12000	135.7	8074	1.11	1.11	1	103.8	13424	102.4	7912	1.37	1.36	0	0	204
2	205	137.7	3391	136.2	7553	1.10	1.05	0	103	10046	102	495	0.98	0.98	0	0	205
2	206	138	3377	136.4	7055	1.17	1.16	0	104.8	13449	103.5	9690	1.26	1.26	1	0	206
2	207	137.7	3999	136.5	7528	0.88	0.86	0	103.4	10935	103	9843	0.39	0.4	1	0	207
2	208	137.5	4919	135.9	7805	1.18	1.16	0	103.3	8928	102.8	5118	0.49	0.49	1	0	208
2	209	137.8	12753	136.2	7824	1.17	1.21	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	209
2	210	137.8	7237	136.6	11342	0.88	0.83	0	103	8801	102.2	6033	0.78	0.82	1	0	210
2	211	137.3	2854	136.6	320	0.51	0.52	1	103.6	9030	103.1	12205	0.48	0.49	1	1	211
2	212	N/A	N/A	N/A	N/A	N/A	N/A	1	103.1	11341	102.7	10020	0.39	0.39	1	1	212
2	213	N/A	N/A	N/A	N/A	N/A	N/A	1	102.9	13322	102.4	9690	0.49	0.47	0	0	213
2	214	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	10071	102.4	9157	0.39	0.39	0	0	214
2	215	N/A	N/A	N/A	N/A	N/A	N/A	1	103.3	4331	103.1	368	0.19	0.21	1	1	215
2	216	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	216
2	217	138.1	3267	136.8	2146	0.95	0.91	0	104.5	8928	102.8	3721	1.65	1.62	0	0	217
2	218	N/A	N/A	N/A	N/A	N/A	N/A	1	103.8	9157	103.4	5271	0.39	0.33	0	0	218
2	219	N/A	N/A	N/A	N/A	N/A	N/A	1	102.6	6541	102.4	3467	0.20	0.16	0	0	219
2	220	N/A	N/A	N/A	N/A	N/A	N/A	1	103	8979	102.6	4966	0.39	0.37	0	0	220
2	221	N/A	N/A	N/A	N/A	N/A	N/A	1	102.9	343	102.7	3772	0.19	0.2	1	1	221
2	222	N/A	N/A	N/A	N/A	N/A	N/A	1	103.2	13195	102.9	10147	0.29	0.32	1	1	222
2	223	N/A	N/A	N/A	N/A	N/A	N/A	1	103.4	8903	102.8	5144	0.58	0.58	0	0	223
2	224	N/A	N/A	N/A	N/A	N/A	N/A	1	103.5	8801	103.1	5550	0.39	0.34	0	0	224
2	225	N/A	N/A	N/A	N/A	N/A	N/A	1	103.2	4280	102.7	3569	0.49	0.48	0	0	225

Row	Tube No.	Maximum Outer Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Outer Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Pass/Fail	Maximum Internal Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Internal Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Pass/Fail	Tube Pass/Fail	Tube No.
2	226	N/A	N/A	N/A	N/A	N/A	N/A	1	103.8	9055	103.3	12560	0.48	0.44	0	0	226
2	227	N/A	N/A	N/A	N/A	N/A	N/A	1	103	4305	102.4	3696	0.59	0.58	0	0	227
2	228	N/A	N/A	N/A	N/A	N/A	N/A	1	103.3	4559	102.9	8217	0.39	0.4	1	1	228
2	229	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	13297	102.5	11824	0.20	0.2	1	1	229
2	230	N/A	N/A	N/A	N/A	N/A	N/A	1	102.4	13246	102.1	9843	0.29	0.26	0	0	230
2	231	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	8852	102.4	4712	0.29	0.33	1	1	231
2	232	N/A	N/A	N/A	N/A	N/A	N/A	1	102.4	8598	102.1	4534	0.29	0.3	1	1	232
2	233	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	4305	102.4	597	0.39	0.35	0	0	233
2	234	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	8496	102.4	4788	0.39	0.42	1	1	234
2	235	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	13297	102.2	9741	0.49	0.48	0	0	235
2	236	N/A	N/A	N/A	N/A	N/A	N/A	1	102.4	13322	102	12738	0.39	0.36	0	0	236
2	237	N/A	N/A	N/A	N/A	N/A	N/A	1	102.4	4229	102.1	572	0.29	0.29	0	0	237
2	238	N/A	N/A	N/A	N/A	N/A	N/A	1	102.1	6464	101.9	4153	0.20	0.19	0	0	238
2	239	N/A	N/A	N/A	N/A	N/A	N/A	1	102.6	8776	102.4	5474	0.20	0.14	0	0	239
2	240	N/A	N/A	N/A	N/A	N/A	N/A	1	103.5	9614	103.1	11570	0.39	0.41	1	1	240
2	241	N/A	N/A	N/A	N/A	N/A	N/A	1	104.7	13348	103.4	9462	1.26	1.23	0	0	241
2	242	N/A	N/A	N/A	N/A	N/A	N/A	1	103.3	4407	102.8	6541	0.49	0.48	0	0	242
2	243	N/A	N/A	N/A	N/A	N/A	N/A	1	103	10579	102.8	13246	0.19	0.15	0	0	243
2	244	N/A	N/A	N/A	N/A	N/A	N/A	1	103.2	6769	102.8	8014	0.39	0.37	0	0	244
2	245	N/A	N/A	N/A	N/A	N/A	N/A	1	103	8547	102.8	5042	0.19	0.17	0	0	245
2	246	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	8801	102	5042	0.69	0.62	0	0	246
2	247	N/A	N/A	N/A	N/A	N/A	N/A	1	104	13449	103	9538	0.97	0.93	0	0	247
2	248	N/A	N/A	N/A	N/A	N/A	N/A	1	102.5	13449	102.3	12281	0.20	0.26	1	1	248
2	249	N/A	N/A	N/A	N/A	N/A	N/A	1	103.2	9081	102.8	12205	0.39	0.42	1	1	249
2	250	N/A	N/A	N/A	N/A	N/A	N/A	1	102.9	9004	102.4	5880	0.49	0.51	1	1	250
2	251	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	13272	102.3	12611	0.49	0.5	1	1	251
2	252	N/A	N/A	N/A	N/A	N/A	N/A	1	103	7709	102.5	5398	0.49	0.44	0	0	252
2	253	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	8852	102.6	5194	0.19	0.19	0	0	253
2	254	N/A	N/A	N/A	N/A	N/A	N/A	1	102.9	9081	102.6	12662	0.29	0.28	0	0	254
2	255	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1	1	255

Row	Tube No.	Maximum Outer Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Outer Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's OD	Maximum % of Growth in Tube's OD	Pass/Fail	Maximum Internal Diameter (mm)	Position of Maximum Diameter (mm)	Minimum Internal Diameter (mm)	Position of Minimum Diameter (mm)	Percentage of Growth in Tube's ID	Maximum % of Growth in Tube's ID	Pass/Fail		Tube Pass/Fail	Tube No.
2	256	N/A	N/A	N/A	N/A	N/A	N/A	1	102.5	8801	102	4940	0.49	0.49	0		0	256
2	257	N/A	N/A	N/A	N/A	N/A	N/A	1	103	10935	102.7	9766	0.29	0.27	0		0	257
2	258	N/A	N/A	N/A	N/A	N/A	N/A	1	103.1	10909	102	7658	1.08	1.02	0		0	258
2	259	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	13500	102.3	10325	0.49	0.46	0		0	259
2	260	N/A	N/A	N/A	N/A	N/A	N/A	1	102.6	8877	102	6236	0.59	0.65	1		1	260
2	261	N/A	N/A	N/A	N/A	N/A	N/A	1	102.5	4255	102.3	3391	0.20	0.24	1		1	261
2	262	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	9589	102.3	12992	0.49	0.44	0		0	262
2	263	N/A	N/A	N/A	N/A	N/A	N/A	1	102.9	13373	102.5	12230	0.39	0.39	0		0	263
2	264	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	8547	102.3	4966	0.39	0.47	1		1	264
2	265	N/A	N/A	N/A	N/A	N/A	N/A	1	103	8954	102.5	7760	0.49	0.44	0		0	265
2	266	N/A	N/A	N/A	N/A	N/A	N/A	1	102.9	8827	102.4	4763	0.49	0.46	0		0	266
2	267	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	13373	102.3	9690	0.39	0.36	0		0	267
2	268	N/A	N/A	N/A	N/A	N/A	N/A	1	102.6	8649	102.4	5093	0.20	0.2	1		1	268
2	269	N/A	N/A	N/A	N/A	N/A	N/A	1	103	8877	102.8	5728	0.19	0.26	1		1	269
2	270	N/A	N/A	N/A	N/A	N/A	N/A	1	103	8903	102.8	5626	0.19	0.25	1		1	270
2	271	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	4538	102.3	6302	0.39	0.41	1		1	271
2	272	N/A	N/A	N/A	N/A	N/A	N/A	1	103.2	9055	102.3	4991	0.88	0.97	1		1	272
2	273	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	273
2	274	N/A	N/A	N/A	N/A	N/A	N/A	1	102.5	8975	102.1	6706	0.39	0.44	1		1	274
2	275	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	9118	102	12982	0.78	0.74	0		0	275
2	276	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	276
2	277	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	277
2	278	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	278
2	279	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	8966	102.4	5329	0.39	0.44	1		1	279
2	280	N/A	N/A	N/A	N/A	N/A	N/A	1	102.5	8958	102	8002	0.49	0.44	0		0	280
2	281	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	281
2	282	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	1		1	282
2	283	N/A	N/A	N/A	N/A	N/A	N/A	1	102.8	8991	102	678	0.78	0.73	0		0	283
2	284	N/A	N/A	N/A	N/A	N/A	N/A	1	102.6	8924	102.4	4840	0.20	0.25	1		1	284
2	285	N/A	N/A	N/A	N/A	N/A	N/A	1	102.4	13386	102.2	9933	0.20	0.21	1		1	285
2	286	N/A	N/A	N/A	N/A	N/A	N/A	1	102.3	6996	102	9093	0.29	0.27	0		0	286
2	287	N/A	N/A	N/A	N/A	N/A	N/A	1	102.4	13282	102.1	9385	0.29	0.25	0		0	287
2	288	N/A	N/A	N/A	N/A	N/A	N/A	1	102.7	8924	102.2	5042	0.49	0.47	0		0	288

A4: Distribution Data on Percentage of Growth

Percentage of Growth in Tube's OD		Percentage of Growth in Tube's ID	
Range	Tubes	Range	Tubes
0.00-0.19	0	0.00-0.19	7
0.20-0.39	1	0.20-0.39	36
0.40-0.59	18	0.40-0.59	21
0.60-0.79	23	0.60-0.79	4
0.80-0.99	46	0.80-0.99	3
1.00-1.19	45	1.00-1.19	1
1.20-1.39	26	1.20-1.39	3
1.40-1.59	25	1.40-1.59	0
1.60-1.79	16	1.60-1.79	1
1.80-1.99	4	1.80-1.99	1
2.00-2.19	2	2.00-2.19	0
2.20-2.39	3	2.20-2.39	0
2.40-2.59	1	2.40-2.59	0
2.60-2.79	0	2.60-2.79	0
2.80-3.00	0	2.80-3.00	0