Weibull Analysis for HP Packings of Secondary Compressor

By : Manoucher Barjesteh Maleki
Maintenance Planning supervisor
Aryasasol Polymer Company(ASPC)

همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

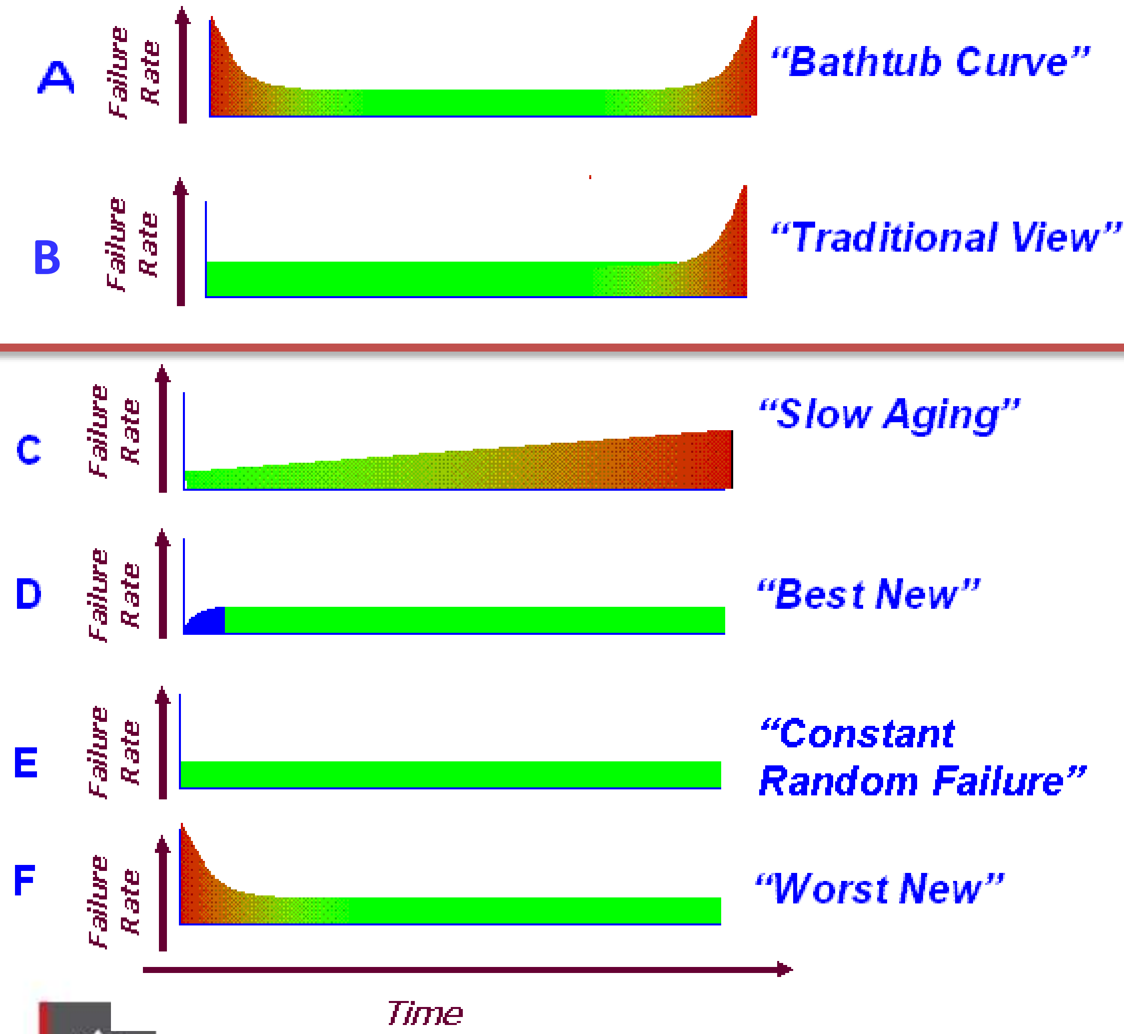
Cost Structure of Repair of HP Packing

Cost Description	Cost Amount(IRR)	Picture
Recondition of Plunger	752,468,132	
Recondition of HP Packing	1,308,941,212	
Recondition of Central Valve	232,555,775	
Recondition of LP Packing	31,929,386	
Man Power for Removing and Installing at site	41,634,900	
Lost Product	4,783,800,000	
Total	**7,151,329,405**	

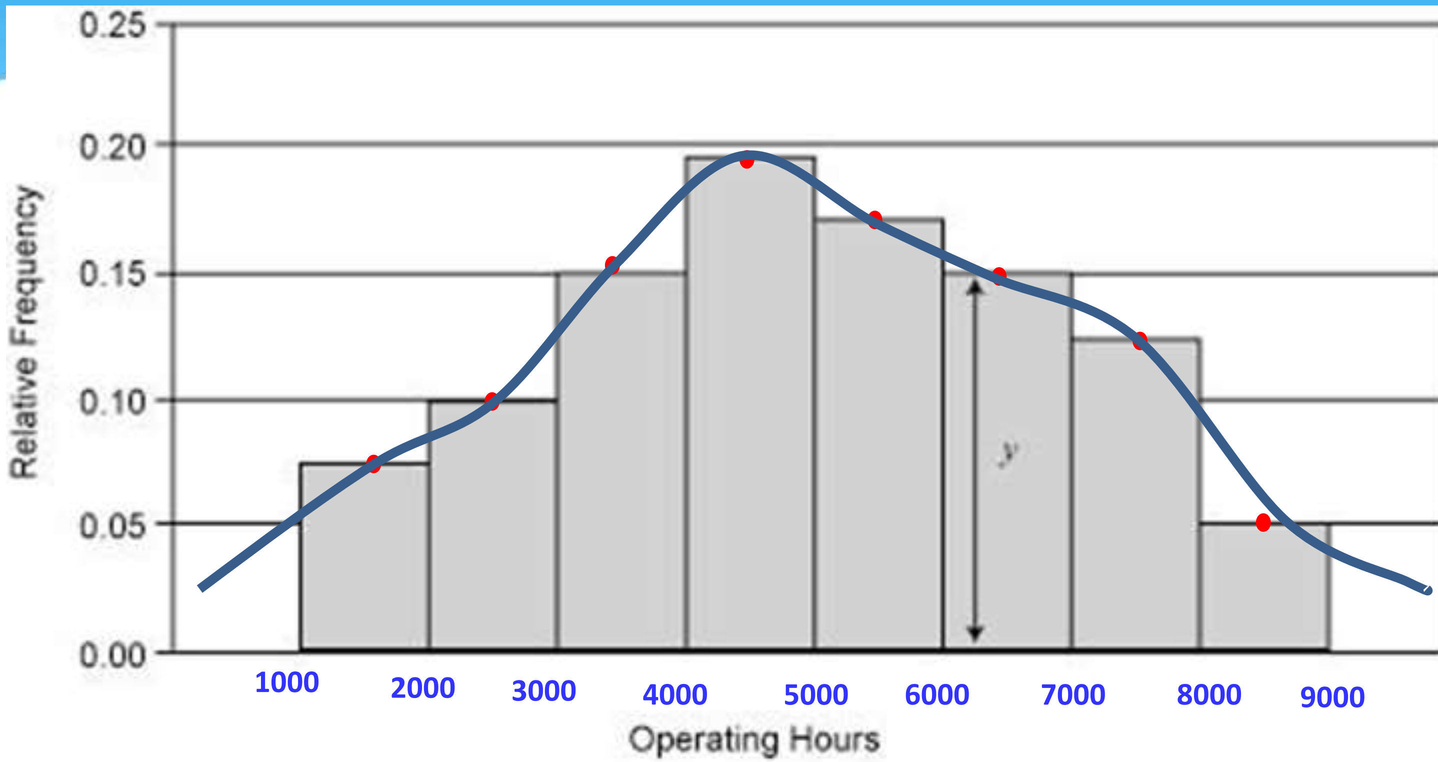
همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

changing view on equipment failure



Probability Density Function

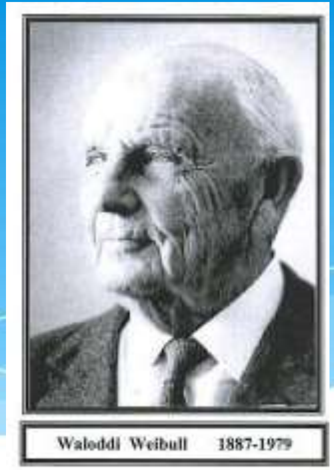


A Histogram of Time to Failure

همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

Weibull Density Function



Weibull distribution is the most commonly used distribution for modeling reliability

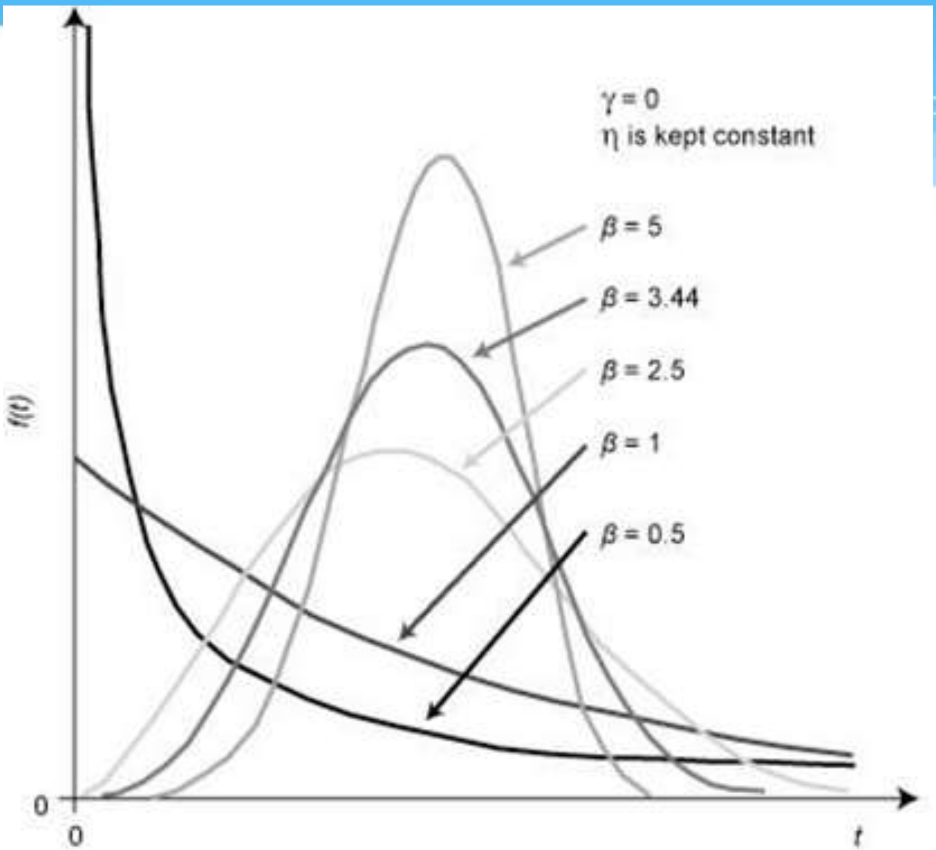
Weibull Probability Density Function (PDF)

$$f(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} \exp\left[-\left(\frac{t}{\eta}\right)^{\beta}\right] \quad \text{for } t \geq 0$$

همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

Weibull Density Function

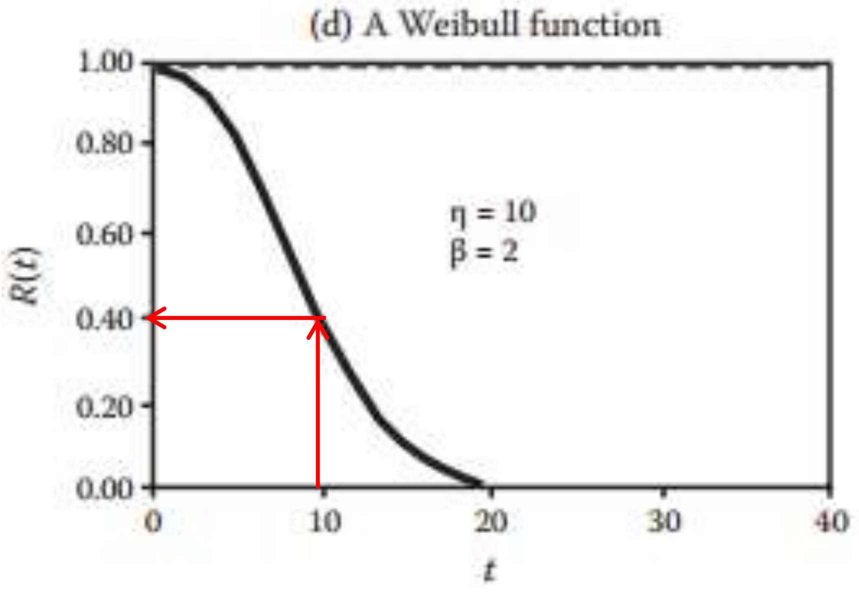


2-Parameter Weibull Functions

Reliability Function *(survival function)*

Reliability function gives the probability of an item operating at least to some specified time without failure

$$R(t) = \exp\left[-\left(\frac{t}{\eta}\right)^{\beta}\right]$$



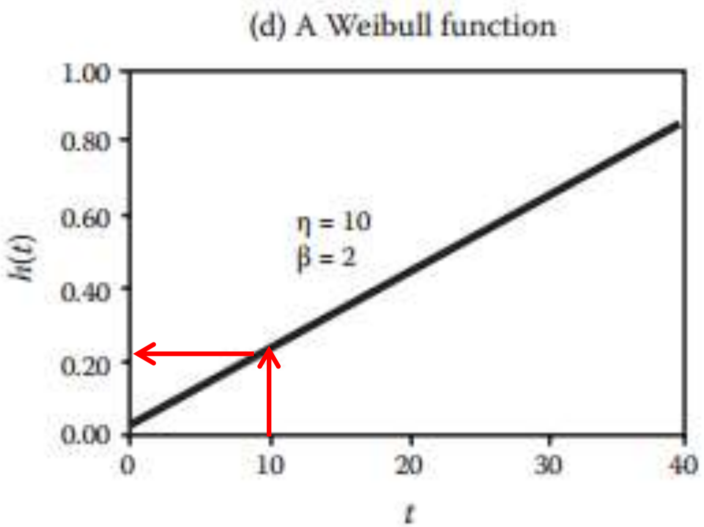
همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

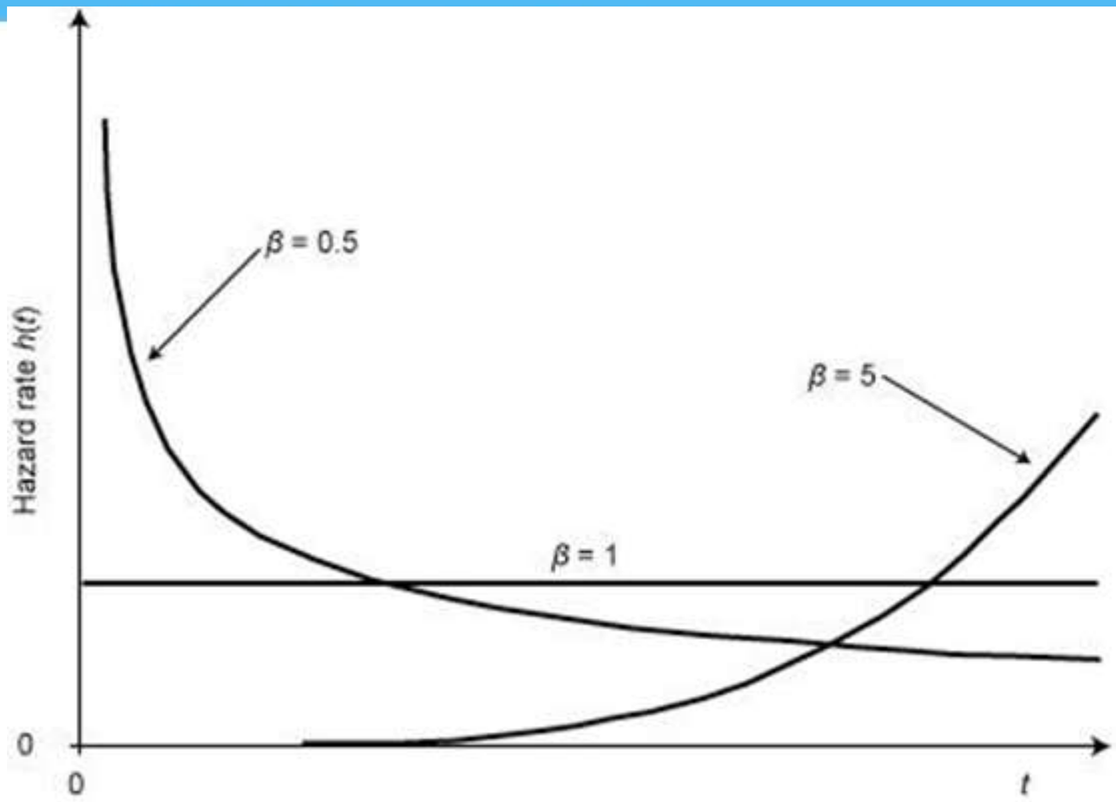
Hazard Function

Conditional probability of failing in the next small interval given survived up to time t

$$h(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1}$$



Hazard Function



Hazard Rate of Weibull Distribution

Trend Test

Laplace Trend Test for checking iid

(Independently Identically Distributed)

$$u = \sqrt{12N(t_n)}\left(\frac{\sum_1^n t_i}{T \cdot N(t_n)} - 0.5\right).$$

Kolmogorov–Smirnov Goodness-of-Fit Test

The Kolmogorov–Smirnov (K-S) test is an appropriate tool to determine if a hypothesized distribution fits a data set or not.

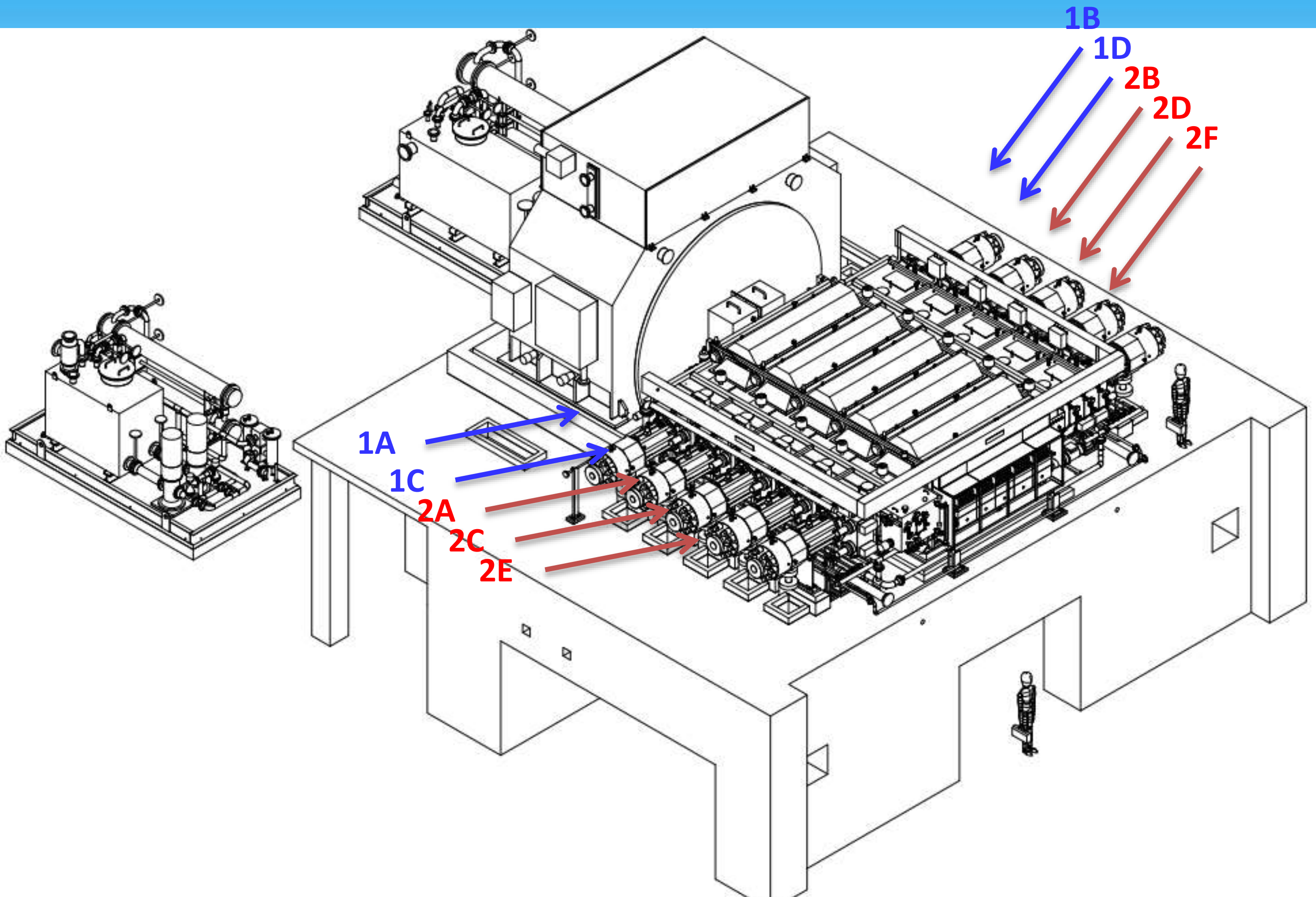
$$d = \max_i \left(\left| F(t_i) - \hat{F}(t_i) \right|, \left| F(t_i) - \hat{F}(t_{i-1}) \right| \right)$$

$\hat{F}(t)$, **sample cumulative distribution function**

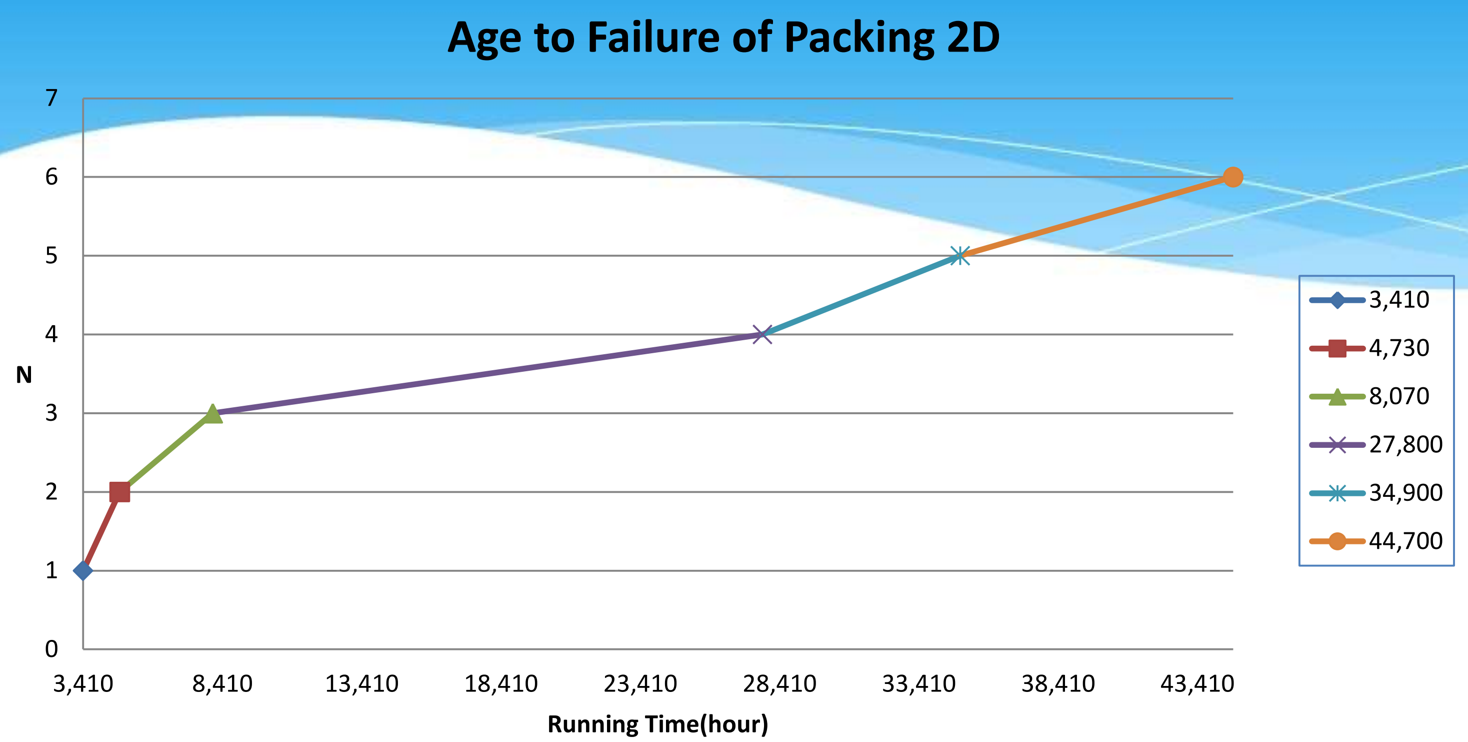
همایش بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

Schematic of Secondary (Hyper) Compressor of LDPE



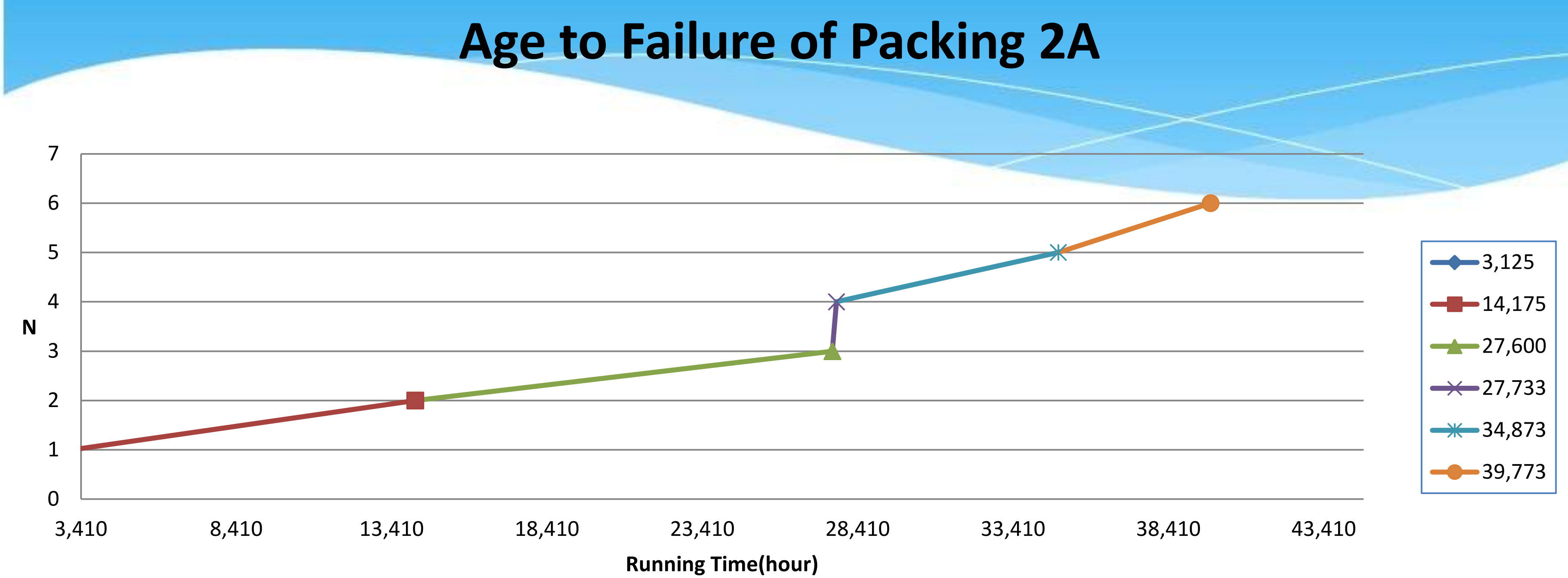
Packing 2D Failure Laplace Test



Laplace Trend Test

As u=-2.32379 is less than u critical -1.96, we can reject the null hypothesis of iid at α= 5% and accept the alternate hypothesis that there is reliability growth

Packing 2A Failure Laplace Test



Laplace Trend Test

At a significance level α of 5%, u critical = +1.96, Because u=0.314 and less than u critical , we can not reject the null hypothesis of being iid.

Packing 2A Failure Data Analysis

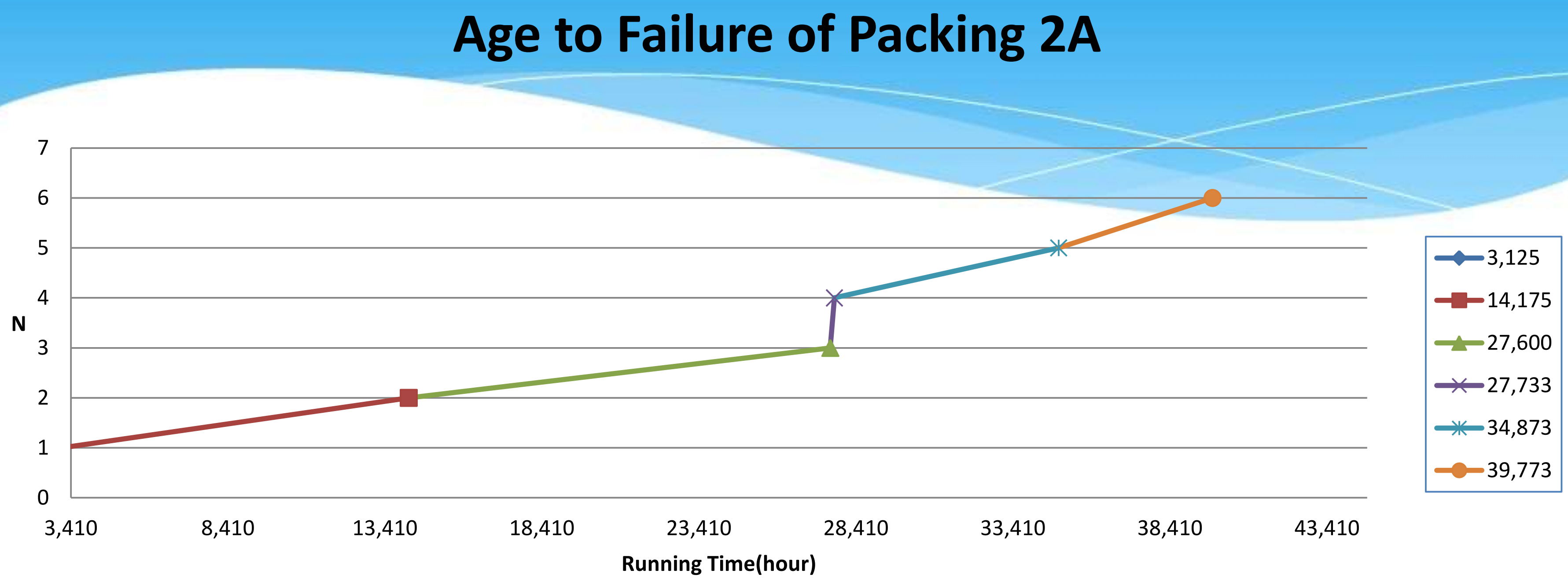
Weibull Analysis of Packing 2A In Excel

			Data To Use For	Excel Regression
The Facts For A Weibull Plot				
i-values	X-age to failure sorted	Y-plot position	Use This Date For X-axis	Use This Date For Y-axis
1	3410	0.109375	-2.15562	8.13446757
2	4730	0.265625	-1.17527	8.46168048
3	8070	0.421875	-0.60154	8.99590876
4	27800	0.578125	-0.14729	10.2327913
5	34900	0.734375	0.281918	10.4602421
6	44700	0.890625	0.794337	10.7077288
Excel Regression Stats				
$\beta=$	1.192			
$\eta=$	28911.960			

همایش بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

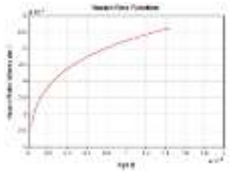
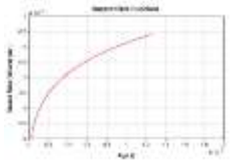
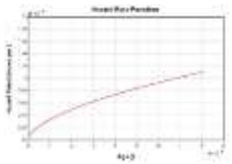
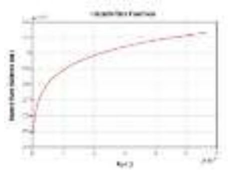
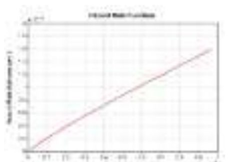
Packing 2A Failure KS Test



KOLMOGOROV–SMIRNOV GOODNESS-OF-FIT TEST

test statistic d is 0.346, and the critical value dα is 0.519 .At the 5% significance level, since d< dα , the fitted Weibull distribution is not rejected

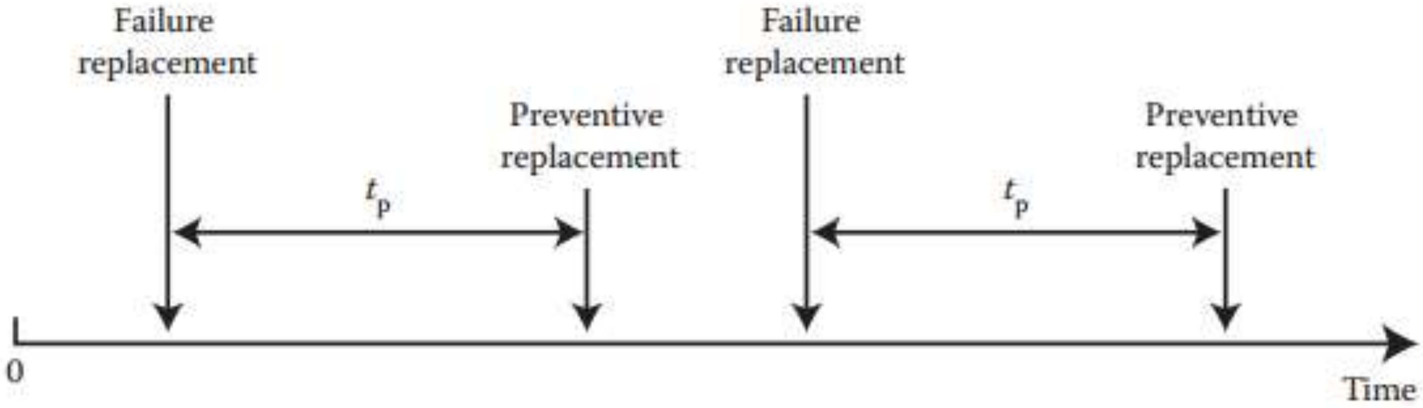
Weibull Analysis In OREST

No	Packing	iid Test(5% significant level)	KS Test(5% significant level)	Shape β	Scale η	Hazard Function
1	2A	OK	OK	1.19	28911	
2	2B	OK	OK	1.19	25364	
3	2C	OK	OK	1.58	26873	
4	2D	NOK(reliability growth)				
5	2E	OK	OK	1.05	37808	
6	2F	OK	OK	1.90	32123	

همایش
بین‌المللی مدیران فنی و نگهداری وتعمیرات

ASPC

Optimal Replacement Interval
Statement of the problem for 2F



Optimal Replacement Interval

$C(t_P)$= Total Expected Replacement Cost per unit time

C_p = Total Cost of Preventive Replacement

C_f = Total Cost of Failure Replacement

$$C(t_P) = \frac{C_P R(t_P) + C_f \left(1 - R(t_P)\right)}{t_P R(t_P) + \int_0^{t_P} t f(t) dt}$$

Optimal Replacement Interval for Packing

$$C(t_P) = \frac{\mathrm{C_f}}{t_P e^{-(t_p/\eta)^{\beta}} + \int_0^{t_P} t_p[\beta/\mu)(t_p/\eta)^{\beta-1} e^{-(t_p/\eta)^{\beta}}]dt}$$

$$\mathrm{C_f} = 7{,}151{,}329{,}405 \ \mathrm{IRR}$$

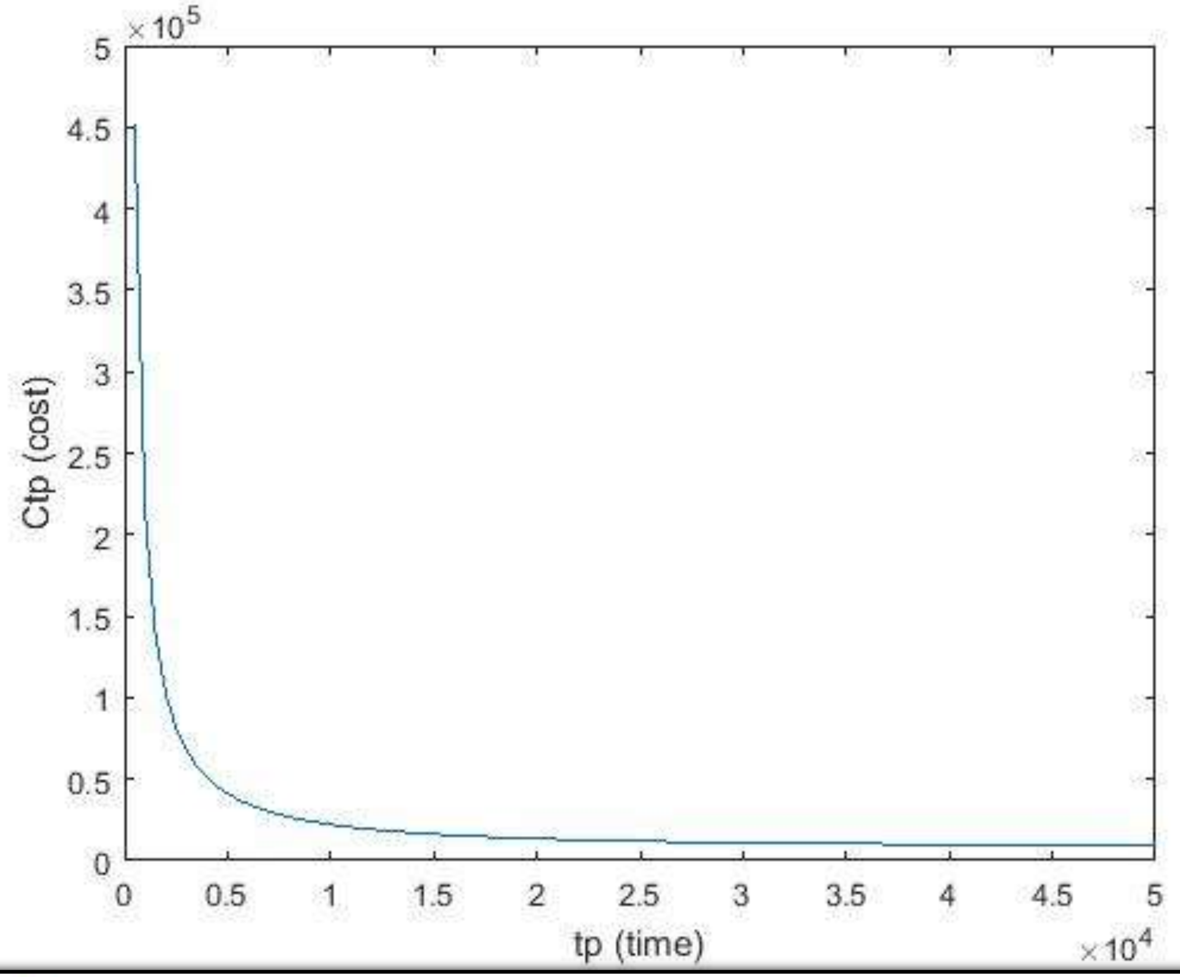
$$\beta = 1.9$$

$$\mu = 32{,}123$$

همایش بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

Cost Function Graph



همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

Weibull Proportional Hazards Model(PHM)

$$h[t, Z(t)] = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} \exp\left\{\sum_{i=1}^{m} \gamma_i z_i(t)\right\}$$

$h[t, Z(t)]$ is the (instantaneous) conditional probability of failure at time t, given the values of z1(t), z2(t),…zm(t).

$z_i(t)$ Each zi(t) in Equation (i= 1, 2,…m) represents a monitored condition data vari-able at the time of inspection

همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

Conclusion

1-Current strategy of changing HP packing based on vibration and leak gas flow seems to be correct .

2-It is crucial to gather precise and comprehensive data of each equipment maintenance data in order to be able to improve our maintenance strategy.

3-Develpopping PHM for HP packings could result in significant improvement in compressor maintenance strategy.

همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC

Thank You for Your Attention

barjastehm@aryasasol.com

همایش
بین‌المللی مدیران فنی و نگهداری و تعمیرات

ASPC