

■ ORIGINAL ARTICLE

## Study of a Two-Unit High-Performance Thin Layer Chromatography System with Partial Failure

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### ABSTRACT

High-Performance Thin Layer Chromatography (HPTLC) is one of the revolutionary techniques that has the advantage of full optimization, minimum sample preparation, automation and hyphenation. Using HPTLC system is used frequently in forensic science for analysis of new drugs, poison, fingerprints, etc. In this paper, we study the major and minor faults of two units of HPTLC system by considering the fact that for minor and major faults, system goes to the partial failure and complete failure, respectively. On occurrence of a fault in a system, either the technician carries out the system to repair or if technician is busy the unit has to wait for repair. Systems parameters are derived by utilizing regenerative point graphical technique. Experimental results are performed to analyze system availability, server visit, busy period and profit. Graphical representations are shown for better understanding of the proposed technique.

**KEYWORDS:** HPTLC, Regenerative Point Graphical Technique, RPGT

### INTRODUCTION

HPTLC IS A MODERN ANALYTICAL method for analyzing chemical behavior of an object. It has wide applications in the field of forensic science due to its time saving nature and economic feasibility.<sup>1-3</sup> Some of its applications can be seen in the fields of poisoning, investigation, doping analysis, fingerprint analysis, analysis of drugs in blood, separating components of a mixture etc.<sup>4-6</sup> It is the fastest chromatography method since chromatography of the instances is performed in parallel. HPTLC technique is known for its purity, uniformity and best accuracy. Due to its importance in

the field of forensic science, it has become an important tool for all researchers working in this area.<sup>7-8</sup>

HPTLC systems are inexpensive, easy and low-cost to install and has a very long service life. In this model, we discuss a two-unit HPTLC system taking both minor and major faults into account, considering online repairing of minor faults. After studying available data on a two-unit HPTLC system, it has been observed that the operative unit goes into failure state on occurrence of major fault. Due to this, sometimes the HPTLC standby unit usually does



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not come into operative state right after manual switching and the two-unit system reduces to single-unit system.

In reliability modeling literature, no researcher has ever discussed an HPTLC system with two units taking various major/minor fault into account. In order to fill this gap, we present a detailed analysis of a two-unit HPTLC system by considering both major as well as minor faults. When a major fault occurs, the unit goes into failure state resulting into non-function of standby unit after manual switching. Minor faults include motor overheating, overload, under or over voltage, abnormal sound, seal broken, etc. Such faults can be repaired online easily. Faults like bearings damage, motor damage, motor burn are examples of major faults, which should be repaired or replaced off-line.

Some assumptions are followed for the present system. First, it goes into partial failure state on occurrence of minor faults and into a state of complete failure, whenever a major fault disrupts the whole system. Secondly, in case of minor fault, technician should deflect the problem within a fraction of time and repair the system online. In case of major faults, the technician should inspect the system first for the faulty component and then carry out the offline repairing or replacing the faulty components, if required.

Gupta<sup>9</sup> constructed the single-unit shock model and analyzed its behavior by using RPGT. Goel *et al.*,<sup>10</sup> analyzed availability of banking server with warm standby unit by using RPGT. In order to analyze the nature of maintenance system, many researchers including<sup>11-13</sup> considered minor, neglected and stoppage on minor faults. Garg *et al.*,<sup>14</sup> measured various performance parameter of a stochastic model of a two-unit hardware software system. It is observed from the literature that researchers never discussed a two-unit HPTLC system by considering both major and minor faults simultaneously.

**OTHER ASSUMPTIONS**

1. Proposed System has two identical units.
2. Faults are self-announcing in the system.

3. Operative, partially failed and failed are the three only modes for each unit.
4. There is a single repair fault facility.
5. All the random variables are mutually independent.

**Notations:**

$\lambda_1/\lambda_2$	Minor/major failure rate
$h_1(t), h_2(t)$	Probability distribution function of repair rate
$H_1(t), H_2(t)$	Cumulative distribution function of repair rate
$O_r/O_w/O_{cs}$	Operative unit under repair/waiting/Oil standby
$F_r/F_w$	Failed unit under repair/waiting

**State Transformation Diagrams**

In State transition diagram, all states are regenerative states while state 3 & 4 are failed states.

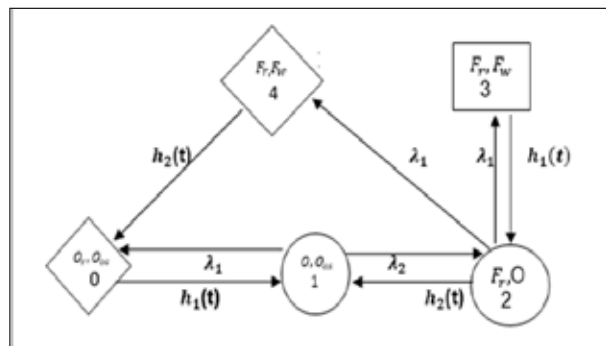


Figure 1 State Transmission Diagram

**Transition Probability and Mean Sojourn Times:**

The probability distribution function for each transition state is given below:

$$\begin{aligned}
 q_{01} &= \lambda_1 e^{-(\lambda_1 + \lambda_2)t} \\
 q_{02} &= \lambda_2 e^{-(\lambda_1 + \lambda_2)t} \\
 q_{20} &= e^{-(\lambda_1 + \lambda_2)t} G_2(t) \\
 q_{23} &= \lambda_1 e^{-(\lambda_1 + \lambda_2)t} G_2(t) \\
 q_{24} &= \lambda_1 e^{-(\lambda_1 + \lambda_2)t} G_2(t) \\
 q_{32} &= H_2(t) \\
 q_{41} &= H_2(t)
 \end{aligned}$$

The Transition probabilities  $p_{ij}$  are obtained Laplace transform of  $q_{ij}$ :

$$\begin{aligned}
 p_{01} &= \lambda_1 / (\lambda_1 + \lambda_2) \\
 p_{02} &= \lambda_2 / (\lambda_1 + \lambda_2) \\
 p_{23} &= \lambda_1 / (\lambda_1 + \lambda_2 + \beta) \rightarrow \lambda_1 [1 - h_2 * (\lambda_1 + \lambda_2)] / (\lambda_1 + \lambda_2) \quad [h_1 = \alpha e^{-\alpha t}] \\
 p_{24} &= \lambda_2 / (\lambda_1 + \lambda_2 + \beta) \rightarrow \lambda_2 [1 - h_2 * (\lambda_1 + \lambda_2)] / (\lambda_1 + \lambda_2) \quad [h_2 = \beta e^{-\beta t}] \\
 p_{20} &= h_2 * (\lambda_1 + \lambda_2) \\
 p_{32} &= 1 \\
 p_{41} &= 1
 \end{aligned}$$

Values of  $R_i(t)$  Reliability:

$$\begin{aligned}
 R_0 &= e^{-(\lambda_1 + \lambda_2)t} \\
 R_1 &= H_1'(t) \\
 R_2 &= e^{-(\lambda_1 + \lambda_2)t} H_2(t) \\
 R_3 &= H_1'(t) \\
 R_4 &= H_2'(t)
 \end{aligned}$$

Values of  $\mu_i(t)$  (Mean Sojourn Times) and

Probability factors  $Z(i, j)$ :

$$\begin{aligned}
 \mu_0 &= 1 / (\lambda_1 + \lambda_2) \\
 \mu_1 &= 1 / \alpha \\
 \mu_2 &= 1 / (\lambda_1 + \lambda_2 + \beta) \\
 \mu_3 &= 1 / \alpha \\
 \mu_4 &= 1 / \beta \\
 Z_{(0,0)} &= 1 \\
 Z_{(0,1)} &= p_{01} + p_{02} p_{24} p_{41} \\
 Z_{(0,2)} &= p_{02} \\
 Z_{(0,3)} &= p_{02} p_{23} \\
 Z_{(0,4)} &= p_{02} p_{04} / (1 - p_{23} p_{32})
 \end{aligned}$$

**Measures of System Effectiveness:** The MTSF and other parameters of the system are calculated by taking state 0 as a base state and using RPGT. Taking particular cases,  $\lambda = \lambda_1 = \lambda_2 = \lambda_3$  &  $W = \alpha = \beta$

**Mean Time to System Failure:** From Figure 1, states  $i=0, 1 \& 3$  are the operative states.

$$\begin{aligned}
 T &= Z_{(0,0)} \mu_0 + Z_{(0,1)} \mu_1 + Z_{(0,2)} \mu_2 + Z_{(0,4)} \mu_4 \\
 T &= \frac{1}{2} [(1/\lambda) + (1/W) + (\lambda/W) (2\lambda + W) + (\lambda/2\lambda) + W + \lambda (\lambda + W)]
 \end{aligned}$$

**Availability:** From Figure 1, all states are regenerative and states  $i = 0, 1 \& 3$  are only available states.

$$\begin{aligned}
 A &= T/D \\
 \text{Where } T &= Z_{(0,0)} \mu_0 + Z_{(0,1)} \mu_1 + Z_{(0,2)} \mu_3 + Z_{(0,4)} \mu_4 \\
 D &= Z_{(0,0)} \mu_0 + Z_{(0,1)} \mu_1 + Z_{(0,2)} \mu_2 + Z_{(0,2)} \mu_3 + Z_{(0,4)} \mu_4
 \end{aligned}$$

**Busy Period of the server:** From figure 1, the server busy at states at  $j=1, 2, 3 \& 4$ . For base state '0'.

$$B = Z_{(0,1)} \mu_1 + Z_{(0,2)} \mu_2 + Z_{(0,2)} \mu_3 + Z_{(0,4)} \mu_4 / D$$

Table 1 MTSF for different value of repair rate.

$\lambda$	T (w = 0.6)	T (w = 0.8)	T (w = 0.9)	T (w=1)
0.01	50.86304	50.64489	50.57252	50.51475
0.02	25.89113	25.66398	25.58888	25.52903
0.03	17.58442	17.34898	17.27134	17.20953
0.04	13.44301	13.19995	13.11992	13.05627
0.05	10.96703	10.71691	10.63465	10.56926
0.06	9.323232	9.066587	8.98223	8.915207
0.07	8.154555	7.891864	7.805542	7.736971
0.08	7.282508	7.014205	6.926036	6.856003

Table 2 Availability for different value of repair rate

$\lambda$	A (w = 0.6)	A (w = 0.8)	A (w = 0.9)	A (w=1)
0.01	0.999736	0.99985	0.999881	0.999903
0.02	0.998995	0.99942	0.999538	0.999623
0.03	0.997851	0.998745	0.998996	0.999178
0.04	0.996367	0.997852	0.998275	0.998584
0.05	0.994602	0.996771	0.997395	0.997854
0.06	0.992607	0.995524	0.996375	0.997005
0.07	0.990426	0.994137	0.995232	0.996047
0.08	0.988098	0.992629	0.993983	0.994996

Table 3 Busy Period

$\lambda$	A (w = 0.6)	A (w = 0.8)	A (w = 0.9)	A (w=1)
0.01	0.017228	0.012882	0.011439	0.010286
0.02	0.035389	0.026437	0.023464	0.021092
0.03	0.054228	0.040535	0.035979	0.03234
0.04	0.073527	0.05506	0.048894	0.043961
0.05	0.093099	0.069909	0.062127	0.05589
0.06	0.112784	0.084988	0.075606	0.068067
0.07	0.132452	0.100215	0.089262	0.080438
0.08	0.151994	0.115519	0.103038	0.092952

Table 4 Server Visits

$\lambda$	T (w = 0.6)	T (w = 0.8)	T (w = 0.9)	T (w=1)
0.01	0.019814	0.019863	0.019879	0.019891
0.02	0.039187	0.039406	0.039477	0.039533
0.03	0.058036	0.058572	0.058745	0.058881
0.04	0.076298	0.077313	0.077641	0.077899
0.05	0.093929	0.095593	0.096132	0.096557
0.06	0.110902	0.113382	0.11419	0.114827
0.07	0.127201	0.13066	0.131794	0.132691
0.08	0.142822	0.147414	0.14893	0.150132

Table 5 Profit

$\lambda$	T (w = 0.6)	T (w = 0.8)	T (w = 0.9)	T (w=1)
0.01	79945.15	79958.65	79962.46	79965.26
0.02	79842.64	79889.43	79902.62	79912.27
0.03	79699.9	79795.65	79822.85	79842.79
0.04	79523.62	79680.4	79725.38	79758.48
0.05	79319.7	79546.5	79612.28	79660.93
0.06	79093.36	79396.56	79485.5	79551.59
0.07	78849.14	79232.94	79346.8	79431.84
0.08	78591	79057.76	79197.82	79302.95

Graphical Study

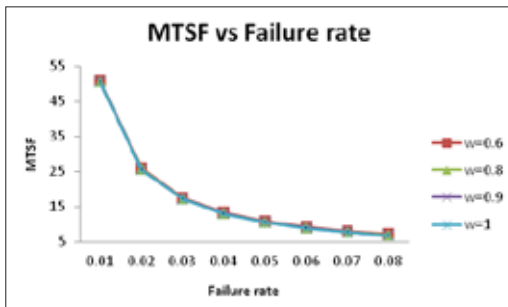


Figure 3 MTSF vs Failure Rate

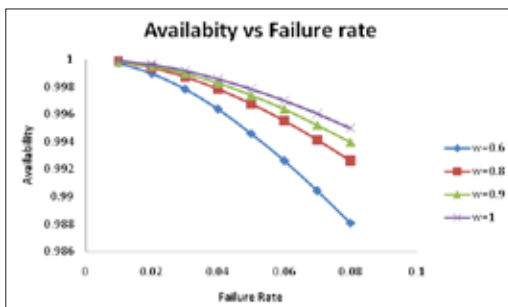


Figure 4 Availability vs Failure Rate

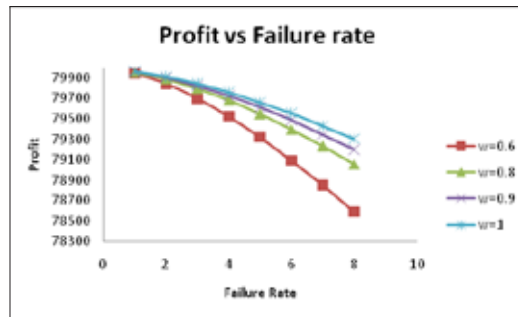


Figure 5 Profit vs Failure Rate

**Expected visits by Server:** From figure 1, the server visits anew for repair at  $j=1,2,3$  & 4.  
 $E=Z_{(0,1)}+Z_{(0,2)}/D$

**Profit:**  $P = C_1A-C_11B-C_11E-C_1$

Where,

$C^0$  = Revenue when the plant is in up-state per unit time

$C^1$  = Cost of repairmen engaging for repair

$C^2$  = Cost of repairmen visit

$C^3$ = Loss during down-state of the plant

RESULT & DISCUSSION

Profit of the system model goes on decreasing with the increases of failure rate. Profit decreases if failed unit has more chances of repair. According to the analysis, there are several revenue cut-offs points in up-time per unit with full capacity to increase the system's profit.

CONCLUSION

A two-unit HPTLC system is considered having major and minor faults with single repairman. By using tables and graphs, we can easily conclude that availability of two-unit HPTLC system decreases with increasing failure rate. Moreover, profit also decreases with increase in failure rate. All performance measures decrease if unit has more chances of complete failure than partial failure. In future, we intend to focus upon the study of performance optimization of two-unit HPTLC system. **IJFMP**

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The authors declare that there is no commercial or financial links that could be construed as conflict of interests.

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