

- **Self Priming Pump:** is a pump that lifts liquid to its suction without the aid of an external priming device and after short time running the pump can suck fluid and can be into normal use.
- **Three Phase:** a continuous series of three over lapping AC cycles offset by 120 degree.
- **Line Voltage:** the voltage between any two of the conductors in a three phase system, it is  $\sqrt{3}$  times higher than phase voltage in a Wye connection.
- **Mechanical Losses:** are the frictional losses that occur in the moving parts of pumps which are in contact (bearings and packing or seals).
- **Hydraulic Losses:** is a summary of internal losses in the impeller and casing due to friction in the walls of the liquid passageways and the continual change of direction of the liquid as it moves through the pump.
- **Volumetric Losses (slip):** This term refers to the leakage of a usually small amount of liquid from the discharge side of a pump to the suction side. Volumetric losses increase as internal clearances are opened up due to wear and erosion in the pump. This causes the pump to run less efficiently and increases BP.
- **Mechanical efficiency:** Efficiency which includes losses in the bearing frame and mechanical seals.
- **Volumetric efficiency:** Efficiency which includes losses due to leakage through the wear rings, balancing holes and vane clearances.
- **Hydraulic efficiency:** Efficiency which includes liquid friction and other losses in the casing and impeller.
- **The overall efficiency:** Efficiency which is the product of three individual efficiencies—mechanical, volumetric and hydraulic.

**For Casing No. 1      No. vanes:      3.0**

|            | <b>Q</b>       | <b>ΔP</b>  | <b>P<sub>H</sub></b> | <b>IP</b>   | <b>η<sub>I</sub></b> |
|------------|----------------|------------|----------------------|-------------|----------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b> | <b>Watt</b>          | <b>Watt</b> | <b>%</b>             |
| 200        | 0.21           | 0.09       | 1.9                  | 492.5       | 0.39%                |
|            | 0.19           | 0.11       | 2.1                  | 442.9       | 0.46%                |
|            | 0.10           | 0.14       | 1.4                  | 491.7       | 0.29%                |
|            |                |            |                      |             |                      |
| 300        | 0.41           | 0.10       | 4.2                  | 583.1       | 0.72%                |
|            | 0.41           | 0.12       | 5.0                  | 604.9       | 0.82%                |
|            | 0.33           | 0.14       | 4.7                  | 461.4       | 1.01%                |
|            | 0.19           | 0.24       | 4.7                  | 486.3       | 0.97%                |
|            |                |            |                      |             |                      |
| 400        | 0.58           | 0.19       | 11.3                 | 569.5       | 1.99%                |
|            | 0.56           | 0.22       | 12.6                 | 609.1       | 2.07%                |
|            | 0.47           | 0.28       | 13.3                 | 617.4       | 2.16%                |
|            | 0.27           | 0.38       | 10.7                 | 569.4       | 1.87%                |
|            |                |            |                      |             |                      |
| 500        | 0.77           | 0.28       | 22.1                 | 487.2       | 4.53%                |
|            | 0.73           | 0.34       | 25.5                 | 557.1       | 4.57%                |
|            | 0.61           | 0.44       | 27.2                 | 581.5       | 4.69%                |
|            | 0.37           | 0.62       | 23.2                 | 662.0       | 3.51%                |
|            |                |            |                      |             |                      |
| 600        | 0.95           | 0.38       | 36.6                 | 458.1       | 8.00%                |
|            | 0.91           | 0.46       | 42.5                 | 458.1       | 9.27%                |
|            | 0.75           | 0.62       | 47.4                 | 598.4       | 7.93%                |
|            | 0.44           | 0.94       | 42.4                 | 732.2       | 5.79%                |
|            |                |            |                      |             |                      |

**For Casing No. 2**

**No.  
vanes:**

**3**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 0.37           | 0.11                         | 4.1                  | 570.2       | 0.72%                      |
|            | 0.29           | 0.12                         | 3.6                  | 441.8       | 0.81%                      |
|            | 0.06           | 0.18                         | 1.1                  | 406.4       | 0.28%                      |
|            |                |                              |                      |             |                            |
| 300        | 0.56           | 0.10                         | 5.8                  | 610.7       | 0.94%                      |
|            | 0.53           | 0.12                         | 6.5                  | 549.7       | 1.18%                      |
|            | 0.45           | 0.20                         | 9.1                  | 519.4       | 1.76%                      |
|            | 0.27           | 0.34                         | 9.4                  | 526.4       | 1.78%                      |
|            |                |                              |                      |             |                            |
| 400        | 1.00           | 0.24                         | 24.4                 | 591.8       | 4.12%                      |
|            | 0.94           | 0.34                         | 32.5                 | 587.8       | 5.53%                      |
|            | 0.74           | 0.54                         | 41.0                 | 616.6       | 6.65%                      |
|            | 0.44           | 0.74                         | 33.3                 | 700.9       | 4.75%                      |
|            |                |                              |                      |             |                            |
| 500        | 1.27           | 0.44                         | 56.8                 | 595.9       | 9.53%                      |
|            | 1.17           | 0.54                         | 64.3                 | 638.9       | 10.06%                     |
|            | 0.93           | 0.74                         | 70.2                 | 650.2       | 10.79%                     |
|            | 0.52           | 1.14                         | 60.7                 | 755.6       | 8.04%                      |
|            |                |                              |                      |             |                            |
| 600        | 1.49           | 0.84                         | 127.9                | 668.2       | 19.14%                     |
|            | 1.47           | 0.94                         | 140.6                | 739.2       | 19.02%                     |
|            | 1.13           | 1.24                         | 142.7                | 813.9       | 17.53%                     |
|            | 0.65           | 1.84                         | 122.9                | 958.7       | 12.82%                     |

**For Casing No. 3**

**No.  
vanes:**

**3**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 0.42           | 0.12                         | 5.1                  | 419.7       | 1.22%                      |
|            | 0.31           | 0.16                         | 5.1                  | 397.9       | 1.28%                      |
|            | 0.14           | 0.20                         | 2.9                  | 569.6       | 0.52%                      |
|            |                |                              |                      |             |                            |
| 300        | 0.93           | 0.28                         | 26.4                 | 705.2       | 3.75%                      |
|            | 0.80           | 0.36                         | 29.2                 | 664.7       | 4.39%                      |
|            | 0.65           | 0.52                         | 34.4                 | 816.7       | 4.22%                      |
|            | 0.42           | 0.64                         | 27.2                 | 900.0       | 3.02%                      |
|            |                |                              |                      |             |                            |
| 400        | 1.37           | 0.54                         | 75.7                 | 827.1       | 9.15%                      |
|            | 1.30           | 0.64                         | 85.0                 | 730.3       | 11.64%                     |
|            | 1.00           | 0.94                         | 96.3                 | 920.5       | 10.46%                     |
|            | 0.57           | 1.26                         | 73.5                 | 1,054.6     | 6.97%                      |
|            |                |                              |                      |             |                            |
| 500        | 2.02           | 1.04                         | 214.0                | 1,303.9     | 16.41%                     |
|            | 1.85           | 1.34                         | 253.1                | 1,173.9     | 21.56%                     |
|            | 1.35           | 1.84                         | 253.9                | 1,041.6     | 24.37%                     |
|            | 0.82           | 2.10                         | 176.4                | 1,386.4     | 12.72%                     |
|            |                |                              |                      |             |                            |
| 550        | 2.27           | 1.34                         | 310.6                | 1,217.7     | 25.51%                     |
|            | 2.06           | 1.54                         | 322.9                | 987.8       | 32.69%                     |
|            | 1.57           | 2.34                         | 375.0                | 1,142.0     | 32.84%                     |
|            | 0.90           | 3.14                         | 288.7                | 1,469.8     | 19.64%                     |
|            |                |                              |                      |             |                            |

**For Casing No. 4**                      **No. vanes: 3**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 0.47           | 0.10                         | 4.8                  | 484.3       | 0.98%                      |
|            | 0.38           | 0.15                         | 5.8                  | 460.6       | 1.26%                      |
|            | 0.18           | 0.20                         | 3.7                  | 548.0       | 0.68%                      |
|            |                |                              |                      |             |                            |
| 300        | 1.00           | 0.25                         | 25.4                 | 685.9       | 3.70%                      |
|            | 0.93           | 0.35                         | 33.1                 | 805.0       | 4.11%                      |
|            | 0.57           | 0.60                         | 35.0                 | 839.0       | 4.17%                      |
|            | 0.37           | 0.75                         | 28.0                 | 813.3       | 3.45%                      |
|            |                |                              |                      |             |                            |
| 400        | 1.53           | 0.52                         | 81.2                 | 935.8       | 8.67%                      |
|            | 1.50           | 0.58                         | 88.6                 | 1,005.7     | 8.81%                      |
|            | 1.10           | 0.98                         | 110.3                | 1,129.1     | 9.77%                      |
|            | 0.60           | 1.64                         | 100.1                | 1,167.7     | 8.57%                      |
|            |                |                              |                      |             |                            |
| 500        | 2.08           | 1.14                         | 241.7                | 1,298.5     | 18.61%                     |
|            | 1.87           | 1.52                         | 290.6                | 1,472.8     | 19.73%                     |
|            | 1.40           | 1.84                         | 262.8                | 1,376.9     | 19.08%                     |
|            | 0.78           | 2.54                         | 202.2                | 1,320.4     | 15.31%                     |
|            |                |                              |                      |             |                            |

**For Casing No. 5**

**No.  
vanes:**

**3**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 0.61           | 0.10                         | 6.2                  | 619.6       | 1.00%                      |
|            | 0.57           | 0.14                         | 8.1                  | 652.6       | 1.24%                      |
|            | 0.42           | 0.22                         | 9.5                  | 918.1       | 1.03%                      |
|            | 0.22           | 0.32                         | 7.3                  | 1,086.3     | 0.67%                      |
|            |                |                              |                      |             |                            |
| 300        | 1.15           | 0.20                         | 23.5                 | 763.8       | 3.07%                      |
|            | 0.91           | 0.38                         | 35.2                 | 891.3       | 3.95%                      |
|            | 0.68           | 0.52                         | 36.3                 | 881.2       | 4.12%                      |
|            | 0.39           | 0.80                         | 31.4                 | 868.1       | 3.62%                      |
|            |                |                              |                      |             |                            |
| 400        | 1.58           | 0.54                         | 87.2                 | 1,047.1     | 8.33%                      |
|            | 1.48           | 0.62                         | 93.8                 | 1,056.8     | 8.88%                      |
|            | 1.06           | 1.10                         | 118.9                | 1,229.4     | 9.67%                      |
|            | 0.65           | 1.64                         | 109.1                | 1,274.0     | 8.56%                      |
|            |                |                              |                      |             |                            |
| 500        | 2.19           | 1.24                         | 276.7                | 1,632.9     | 16.94%                     |
|            | 1.95           | 1.54                         | 305.9                | 1,613.7     | 18.95%                     |
|            | 1.39           | 1.90                         | 268.9                | 1,446.5     | 18.59%                     |
|            | 0.74           | 2.64                         | 198.4                | 1,508.0     | 13.16%                     |
|            |                |                              |                      |             |                            |

**For Casing  
No. 1**

**No. 4  
vanes:**

|            | <b>Q</b>       | <b>ΔP</b>  | <b>P<sub>H</sub></b> | <b>IP</b>   | <b>η<sub>I</sub></b> |
|------------|----------------|------------|----------------------|-------------|----------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b> | <b>Watt</b>          | <b>Watt</b> | <b>%</b>             |
| 200        | 0.41           | 0.10       | 4.2                  | 372.6       | 1.12%                |
|            | 0.30           | 0.14       | 4.3                  | 372.6       | 1.15%                |
|            | 0.10           | 0.22       | 2.3                  | 442.4       | 0.52%                |
|            |                |            |                      |             |                      |
| 300        | 0.65           | 0.10       | 6.7                  | 558.9       | 1.19%                |
|            | 0.63           | 0.12       | 7.7                  | 559.6       | 1.37%                |
|            | 0.48           | 0.26       | 12.8                 | 627.7       | 2.04%                |
|            | 0.26           | 0.44       | 11.6                 | 714.4       | 1.62%                |
|            |                |            |                      |             |                      |
| 400        | 0.89           | 0.14       | 12.7                 | 545.4       | 2.33%                |
|            | 0.85           | 0.24       | 20.7                 | 596.4       | 3.48%                |
|            | 0.66           | 0.48       | 32.3                 | 605.3       | 5.33%                |
|            | 0.37           | 0.82       | 30.6                 | 565.9       | 5.41%                |
|            |                |            |                      |             |                      |
| 500        | 1.17           | 0.24       | 28.6                 | 476.6       | 5.99%                |
|            | 1.11           | 0.38       | 43.0                 | 531.3       | 8.09%                |
|            | 0.88           | 0.74       | 66.2                 | 598.5       | 11.06%               |
|            | 0.50           | 1.24       | 63.5                 | 675.5       | 9.40%                |
|            |                |            |                      |             |                      |
| 600        | 1.43           | 0.42       | 61.1                 | 576.1       | 10.60%               |
|            | 1.35           | 0.58       | 80.1                 | 601.7       | 13.31%               |
|            | 1.10           | 1.14       | 128.0                | 660.1       | 19.39%               |
|            | 0.62           | 1.90       | 120.3                | 803.2       | 14.97%               |
|            |                |            |                      |             |                      |

**For Casing No. 2**

**No.  
4  
vanes:**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 0.69           | 0.10                         | 7.0                  | 420.6       | 1.67%                      |
|            | 0.52           | 0.15                         | 8.0                  | 420.6       | 1.89%                      |
|            | 0.36           | 0.18                         | 6.6                  | 435.9       | 1.51%                      |
|            | 0.12           | 0.28                         | 3.4                  | 460.6       | 0.73%                      |
|            |                |                              |                      |             |                            |
| 300        | 0.92           | 0.10                         | 9.4                  | 367.6       | 2.55%                      |
|            | 0.82           | 0.18                         | 15.0                 | 465.6       | 3.22%                      |
|            | 0.58           | 0.34                         | 20.2                 | 467.8       | 4.32%                      |
|            | 0.33           | 0.52                         | 17.3                 | 452.8       | 3.83%                      |
|            |                |                              |                      |             |                            |
| 400        | 1.21           | 0.24                         | 29.6                 | 467.0       | 6.33%                      |
|            | 1.11           | 0.36                         | 40.8                 | 474.2       | 8.60%                      |
|            | 0.83           | 0.64                         | 54.4                 | 568.4       | 9.57%                      |
|            | 0.44           | 0.94                         | 42.2                 | 548.7       | 7.68%                      |
|            |                |                              |                      |             |                            |
| 500        | 1.53           | 0.44                         | 68.8                 | 535.0       | 12.86%                     |
|            | 1.38           | 0.58                         | 81.8                 | 526.9       | 15.52%                     |
|            | 1.04           | 0.98                         | 104.4                | 595.2       | 17.53%                     |
|            | 0.55           | 1.44                         | 81.3                 | 732.1       | 11.11%                     |
|            |                |                              |                      |             |                            |
| 600        | 1.93           | 0.72                         | 141.8                | 635.5       | 22.32%                     |
|            | 1.74           | 0.94                         | 167.2                | 562.5       | 29.72%                     |
|            | 1.29           | 1.54                         | 202.9                | 729.2       | 27.82%                     |
|            | 0.68           | 2.24                         | 155.8                | 883.1       | 17.64%                     |

**For Casing No.3 & 4 vanes**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 0.97           | 0.14                         | 13.91                | 278.8       | 6.91%                      |
|            | 0.88           | 0.24                         | 21.60                | 247.6       | 8.72%                      |
|            | 0.78           | 0.30                         | 23.92                | 297.6       | 8.04%                      |
|            | 0.62           | 0.36                         | 22.63                | 344.7       | 6.56%                      |
|            |                |                              |                      |             |                            |
| 300        | 1.64           | 0.64                         | 107.14               | 668.4       | 16.03%                     |
|            | 1.52           | 0.84                         | 130.10               | 691.5       | 18.81%                     |
|            | 1.34           | 1.04                         | 141.98               | 924.5       | 15.36%                     |
|            | 1.11           | 1.24                         | 139.87               | 1,179.4     | 11.86%                     |
|            | 0.57           | 1.64                         | 94.97                | 1,543.7     | 6.15%                      |
|            |                |                              |                      |             |                            |
| 400        | 2.32           | 1.10                         | 260.50               | 1,252.4     | 20.80%                     |
|            | 2.07           | 1.44                         | 304.64               | 1,172.3     | 25.99%                     |
|            | 1.80           | 1.64                         | 301.02               | 1,376.2     | 21.87%                     |
|            | 1.37           | 2.24                         | 313.91               | 1,819.7     | 17.25%                     |
|            | 1.31           | 2.34                         | 311.71               | 1,903.5     | 16.38%                     |
|            |                |                              |                      |             |                            |
| 500        | 2.97           | 1.84                         | 556.68               | 1,760.8     | 31.62%                     |
|            | 2.57           | 2.34                         | 614.25               | 1,588.1     | 38.68%                     |
|            | 2.25           | 2.64                         | 607.07               | 1,736.1     | 34.97%                     |
|            | 1.73           | 3.14                         | 553.57               | 2,006.4     | 27.59%                     |
|            |                |                              |                      |             |                            |

**For Casing No.4 & 4 vanes**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 1.53           | 0.24                         | 37.41                | 518.8       | 7.21%                      |
|            | 1.27           | 0.32                         | 41.54                | 562.1       | 7.39%                      |
|            | 1.15           | 0.38                         | 44.48                | 637.1       | 6.98%                      |
|            | 0.47           | 0.64                         | 30.46                | 994.6       | 3.06%                      |
|            |                |                              |                      |             |                            |
| 300        | 2.30           | 0.54                         | 126.41               | 702.4       | 18.00%                     |
|            | 2.09           | 0.60                         | 127.88               | 704.4       | 18.15%                     |
|            | 1.75           | 0.74                         | 132.09               | 912.4       | 14.48%                     |
|            | 0.49           | 1.84                         | 92.71                | 1,849.6     | 5.01%                      |
|            |                |                              |                      |             |                            |
| 400        | 2.98           | 0.70                         | 212.68               | 972.1       | 21.88%                     |
|            | 2.64           | 0.90                         | 242.49               | 963.5       | 25.17%                     |
|            | 2.30           | 1.40                         | 327.74               | 1,388.1     | 23.61%                     |
|            | 0.64           | 3.42                         | 221.99               | 3,030.1     | 7.33%                      |
|            |                |                              |                      |             |                            |
| 500        | 3.50           | 1.26                         | 449.82               | 1,310.8     | 34.36%                     |
|            | 3.18           | 1.64                         | 532.25               | 1,527.9     | 34.83%                     |
|            | 2.59           | 2.42                         | 639.96               | 1,996.6     | 32.05%                     |
|            | 0.76           | 4.14                         | 319.56               | 2,329.4     | 13.72%                     |
|            |                |                              |                      |             |                            |

**For Casing No.5 & 4 vanes**

|            | <b>Q</b>       | <b><math>\Delta P</math></b> | <b>P<sub>H</sub></b> | <b>IP</b>   | <b><math>\eta_I</math></b> |
|------------|----------------|------------------------------|----------------------|-------------|----------------------------|
| <b>rpm</b> | <b>Lit/sec</b> | <b>Bar</b>                   | <b>Watt</b>          | <b>Watt</b> | <b>%</b>                   |
| 200        | 1.59           | 0.34                         | 55.17                | 849.9       | 6.49%                      |
|            | 1.43           | 0.46                         | 67.03                | 906.1       | 7.40%                      |
|            | 1.30           | 0.52                         | 68.76                | 962.1       | 7.15%                      |
|            | 0.39           | 0.84                         | 33.32                | 1,469.1     | 2.27%                      |
|            |                |                              |                      |             |                            |
| 300        | 2.46           | 0.74                         | 185.39               | 1,103.1     | 16.81%                     |
|            | 2.22           | 0.84                         | 190.40               | 1,111.3     | 17.13%                     |
|            | 2.06           | 0.98                         | 205.80               | 1,209.7     | 17.01%                     |
|            | 1.10           | 1.64                         | 183.25               | 2,409.7     | 7.60%                      |
|            |                |                              |                      |             |                            |
| 400        | 2.97           | 1.04                         | 314.64               | 1,808.5     | 17.40%                     |
|            | 2.69           | 1.14                         | 313.06               | 1,344.1     | 23.29%                     |
|            | 2.06           | 1.74                         | 365.40               | 2,068.8     | 17.66%                     |
|            | 1.10           | 2.94                         | 330.06               | 3,657.5     | 9.02%                      |
|            |                |                              |                      |             |                            |
| 500        | 3.89           | 1.34                         | 531.53               | 1,851.6     | 28.71%                     |
|            | 3.29           | 1.94                         | 651.84               | 1,886.2     | 34.56%                     |
|            | 2.41           | 2.74                         | 674.61               | 2,350.0     | 28.71%                     |
|            | 0.78           | 4.34                         | 344.31               | 2,773.1     | 12.42%                     |
|            |                |                              |                      |             |                            |

## **Uncertainty Analysis:**

No measurement made is ever exact. The exactness of measurement is always limited by the degree of refinement of the apparatus used, by skill of the observer, and by the basic physics in the experiment.

For a single observation, the error, which is the difference between the true and observed values, is a certain fixed number. But the uncertainty, or what one thinks the error might be, may vary considerably depending upon the particular circumstances of observation.

To know how reliable the experimental result is, it is necessary to compute the uncertainty in the results from the estimates of uncertainty in the measured values.

Kline and Mc.clintock [16] nicely described a mathematical technique for estimation of uncertainty analysis into experimental results.

The uncertainty in each variable described as:

$$\text{Variable value} = m \pm w$$

Where, m is the mean (arithmetic mean of the observed value) and w is the uncertainty interval.

If R is linear function of n independent variables,  $v_1, v_2, \dots v_n$  each of which is normally distributed, then the relation between the interval for the variables  $w_i$ , and the interval for the result  $W_R$  is as follows:

$$W_R = \sqrt{\left(\frac{\partial R}{\partial v_1} \times W_1\right)^2 + \left(\frac{\partial R}{\partial v_2} \times W_2\right)^2 + \dots \dots \left(\frac{\partial R}{\partial v_n} \times W_n\right)^2}$$

This equation might be used directly as an approximation for calculating the uncertainty interval in the result.

- The uncertainty of water flow rate:

$$Q = V/t$$

$$E_Q = \sqrt{\left(\frac{\partial Q}{\partial t} \times E_t\right)^2}$$

$$\frac{\partial Q}{\partial t} = -\frac{V}{(t)^2}$$

$$E_t = \pm 1 \text{ [sec]}$$

$$\frac{\partial Q}{\partial t} = -\frac{V}{(t)^2} = -0.0001 \frac{m^3}{sec}$$

$$E_Q = \sqrt{\left(\frac{\partial Q}{\partial t} \times E_t\right)^2} = \pm 10^{-4} \text{ [m}^3/\text{s]}$$

- The uncertainty of the Break Power:

$$BP = \sqrt{3} \times I \times V \times \cos\phi \times \eta_{Mo} = Const. \times I \times V$$

Where,

Motor power factor  **$\cos\phi = 0.8$**  & Motor Efficiency

**$\eta_{Mo} = 80\%$**

So,  **$Const. = 1.1085$**

$$E_p = \sqrt{\left(\frac{\partial P}{\partial I} \times E_I\right)^2 + \left(\frac{\partial P}{\partial V} \times E_V\right)^2} = 10^{-4} \text{ [m}^3/\text{s]}$$

$$\frac{\partial P}{\partial I} = \text{Const.} \times V$$

$$\frac{\partial P}{\partial V} = \text{Const.} \times I$$

For  $E_I = \pm 10^{-3} \text{ [Ampere]}$

$$E_V = \pm 1 \text{ [Volt]}$$

$$E_p = \pm 14.73 \text{ [watt]}$$

### Sample of calculations:

For 3 blades rotor and Casing No.2 at 500 rpm:

➤ Hydraulic power:

| Flow rate (m3/sec)        | Measured ΔP (bar) | Pressure (m H2o) |
|---------------------------|-------------------|------------------|
| $0.9296 \times 10^{(-3)}$ | 0.74              | 7.54             |

$$\bullet P_h = \rho \times g \times Q \times H = \gamma \times Q \times H = 70.17 \text{ (watt)}$$

➤ Brake Power:

| Measured Current (I) | Measured line to line Voltage |
|----------------------|-------------------------------|
| 3.64                 | 393                           |

$$\bullet BP = \sqrt{3} \times I \times V \times \cos\phi \times \eta_{M0} = 1,588 \text{ (watt)}$$

| Measured Current (I0) at no | Measured Voltage (V0 ) at no |
|-----------------------------|------------------------------|
| 2.85                        | 380                          |

$$\bullet P_{ml} = \sqrt{3} \times I_0 \times V_0 \times \cos\phi_0 = 937 \text{ (watt)}$$

$$\bullet IP = BP - P_{ml} = 650 \text{ (watt)}$$

➤ Efficiency:

$$\bullet \eta_M = IP \div BP = 40.9\%$$

$$\bullet \eta_I = P_h \div IP = 10.79\%$$

$$\bullet \eta_o = P_h \div BP = 4.42\%$$