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Through Pass Rate Improvement in a Assembly Line by BPS Methodology: A Case Study of a Manufacturing Company

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Abstract

The fast changing economic conditions such as global competitions, declining profit margin, customer demand for high quality product, product variety and reduced lead time etc. had a major impact on manufacturing industries.This work discusses about the successful implementation of Basic Problem Solving (BPS) methodology to improve the through pass rate of a Gear Box assembly line in a large scale manufacturing company. Each and every Gearbox is tested to ensure that there are no defects. Gear Box once rejected are again reworked and tested to ensure their performance, this increases the cost of production of gear boxes.The objective of this work is to improve the through pass rate of Gearbox assembly line. Rejection data from the each test beds are collected and analysis were made to find the root causes for the rejection of gear box. Solutions were identified and validated for the root causes. After pilot implementation of solutions, rejection data was again collected and checked for improvement. It was found out that the through pass rate has increased.

Keywords– Manufacturing, Through Pass Rate, Pareto Analysis, Cause and Effect Diagram, Six Sigma

Introduction

In an Automobile Sector, success of an organisation resides in its ability to respond quickly to its need of the customers[4]. The customer needs must be attended with minimum manufacturing costs and minimum lead time[4]. This can be identified by the manufacturing metrics.Through pass Rate (TPR) is one of the manufacturing metric and is defined as the number of units coming out of a process divided by the number of units going into that process over a specified period of time. Only good units with no rework or scrap are counted as coming out of an individual process. The goal of every manufacturer is to eliminate rework in favour of improving TPR to achieve the lowest product costs possible[3]. But to do this requires a methodology for accurately measuring and tracking TPR throughout the manufacturing process, since it is impossible to consistently improve or maintain something that isn't quantified. This involves recording results at each step in such a way that TPR can be calculated while properly accounting for the rework and re-testing of failed parts.[1] This work is carried out by Basic Problem Solving (BPS) methodology. The BPS methodology has seven steps namely Define, Observation, Analysis, Action, Check, Standardize and conclude. Each step has its own quality tools such as Pareto chart, Check sheet, Control chart, Hypothesis testing, Cause and effect diagram, Design of experiments, etc.

The project requires support from Manufacturing, Quality, Unit planning and Logistics.

During testing, a Gearbox is checked for defects such as noise, oil leak, gear engagement issues, reverse switch malfunctioning, tightness of flange, vibration, etc. Rejections data were collected and a pareto analysis was made to find out the most frequently occurring reasons for rejections. Since Oil Leakage accounts for almost 30% of the total Gearbox rejection, this work focuses only on Oil leakage reduction to improve the thro pass rate. Improving the thro pass rate leads to reduction in operator effort, improvement in quality and increased cost savings[2]. All the plots were plotted using Minitab Software.

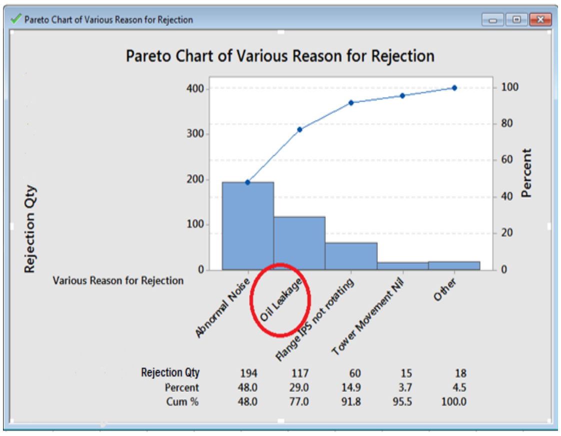

Fig 1: Pareto Chart showing the amount of rejections for various reasons

Literature Review and Survey

Literature survey focuses on implementation of Six Sigma in manufacturing Industries, Methodology followed for this work is BPS, but still Six Sigma and BPS have a close correlation. Five Steps of Six Sigma is made more wide as seven steps in

Basic Problem Solving Methodology. The following are the areas where Six Sigma is applicable in a automobile Industry,[4]

- Improving safety and reliability of finished vehicles.
- Reducing manufacturing defects at each stage.
- Reducing time to manufacture.
- Reducing variation in all the critical parameters that impact the finished product.
- Improving the overall incoming material quality or parts quality.
- Reducing supplier lead time.

Basic Problem Solving methodology was followed to improve the TPR of GearBox assembly line. It is also a breakthrough business strategy used for quality and process improvement by using a set of structured tools and statistical measures to evaluate processes.[1]

CASE STUDY

Phase 1: PROBLEM

The frequency of the problem was analysed by the Quality management team. In this case there were rejections in the assembled gearbox when it was tested. The gearboxes are rejected due to various reasons. This affects the through pass rate of the gearbox assembly line which eventually affects the chassis assembly and it brings down the overall production rate of the factory. It also gives rise to the inventory of the other parts which is needed in the chassis assembly.

Now, to increase the through pass rate the major cause for the rejection is to be found and the various ways of attacking the cause has to be decided which can ultimately increase the production rate.

Phase 2 : OBSERVATION

In order to find the major reasons contributing to the problem, real time data were collected from all the test beds. Details of the tested gearboxes were collected, which includes shift, model, reason for rejection, tested quantity and rejected quantity. The reasons for rejection included Noise, Flange not rotating, Tower movement, Oil leak, Gear not engaging, Flange wobbling, Broken nozzle, Power Take Off not working, etc. With the collected data a Pareto Analysis was made to narrow down on the major cause. It showed that NoiseProblem was at the peak and oil leak at the second place. Oil leak issue was taken as it fell under the scope of BPS methodology.

Checking for Binomial Distribution

Being attribute data, rejection data follows Binomial distribution. To find this, several steps has to be followed. They are,

Step 1: Histogram was plotted with the rejected data.

Step 2: Probability Plot (with fit) P-value > 0.05. was plotted.

Step 3: Control Chart (P-Chart) was plotted.

Step 3: Process capability Plot was plotted.

Step 1

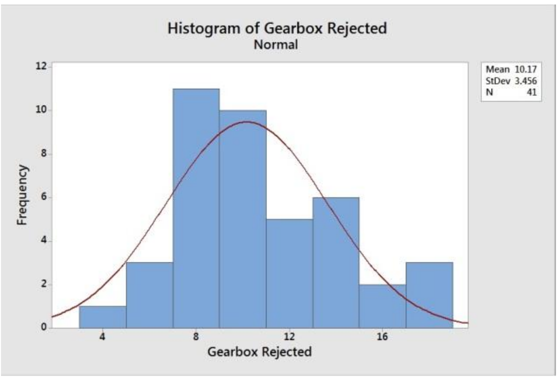

Fig 2: Histogram of Gear Box Rejected

In this plot it showed the rejection of Gear Boxes for various reasons such as Abnormal noise, Oil Leak, Tower movement, Gear not engaging etc.

Step 2:

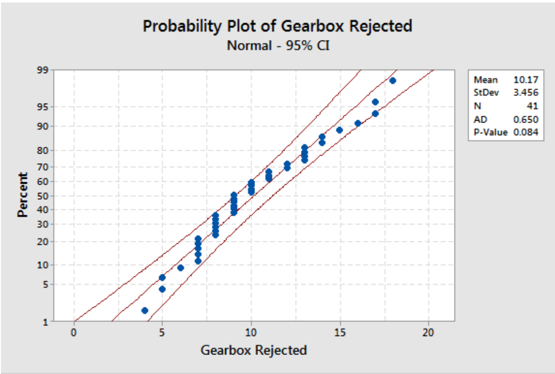

Fig 3: Probability plot of Gearbox Rejected

The purpose of a probability plot is to check the P-value with the collected data. Since the P- value is greater than 0.05.It was concluded that data was following binomial distribution.

Step 3:

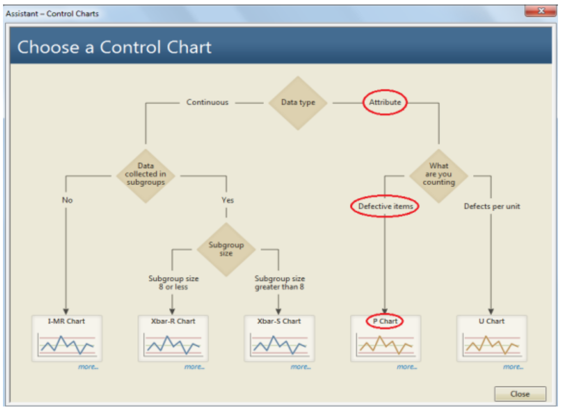

Fig 4 : Choosing a Control Chart

Calculation of UCL and LCL

$\sigma = \sqrt{\frac{p(1-p)}{n}}$

z=3

UCL = $p + z\sigma$

= $p + z\sqrt{\frac{p(1-p)}{n}}$

=0.0604 + 3 $\sqrt{\frac{0.0604\,(1-0.0604)}{41}}$

UCL =0.1504

LCL = $p + z\sigma$

= $p - z\sqrt{\frac{p(1-p)}{n}}$

= 0.0604 - 3 $\sqrt{\frac{0.0604\,(1-0.0604)}{41}}$

LCL = -0.03004 = 0 (Since negative value is not possible, 0 is considered)

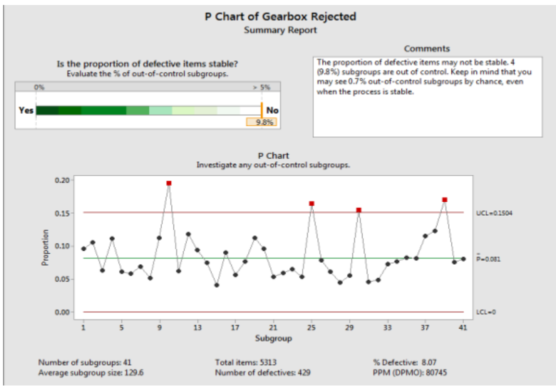

Fig 5: Control Chart

From the above plot it was clear that the rejection data follows binomial distribution and the rejections are stable.

Step 4:

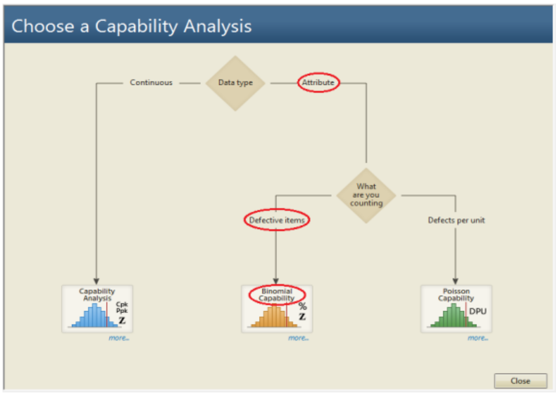

Fig 6: Choosing capability plot

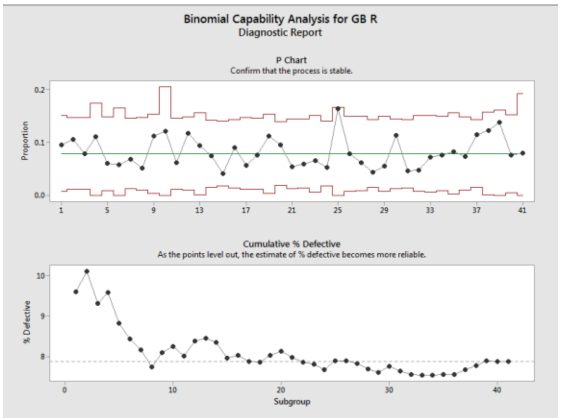

Fig 7: Process Capability plot

If the process is not in statistical control then capability has no meaning. Therefore the process capability does not deal with special cause variation but only common cause variation.

Phase 3: ANALYSIS

Analysis done to arrive at the Root causes of the problem. This was done using Pareto analysis and Cause and Effect diagram with the collected data. The data collected from the test beds were sorted into 4 different forms,

- Test Bedwise Rejections
- Reasonwise Rejections
- Shiftwise Rejections
- Modelwise Rejections

Test Bedwise Rejections

The data were taken from four test beds and the number of gear boxes rejected in each test bed each day per shift was summed and a pareto analysis was done. From the analysis it was found out that the rejections are similar inall the test beds. Therefore it was concluded that there was no problem with the test beds.

Table 1: Rejection details of gearboxes from each test bed

Test Bed	GB Tested	GB Rejected	GB Rejected %
1	1819	20	1.09
2	1745	25	1.43
3	1898	33	1.73
4	1817	22	1.22

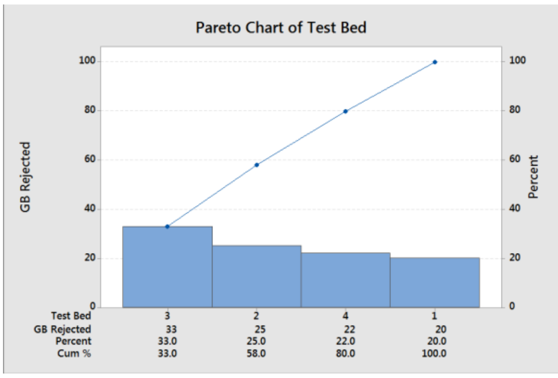

Fig 8: Pareto Chart for Test Bed rejections

Model wise Rejections

There are about 10 series of Gear Box being assembled and tested. Few series have more demand while some have less demand. Based upon the number of gear boxes assembled in a particular series and got rejected,apareto analysis was made to check whether there is any rejections occurring frequently in any particular series. From this chart it was evident all the models have similar rate of rejections. So we conclude that the there is no problem with any particular model.

Table 2: Rejection details of Gear Boxes modelwise

Series	GB Tested	GB Rejected	GB Rejected %
81	320	20	6.250
105	196	16	8.163
107	80	4	5.000
114	385	28	7.270
78	122	8	6.550
89	129	9	6.970
84	122	8	6.550
92	160	11	6.870
93	13	1	7.690
167	12	1	8.330

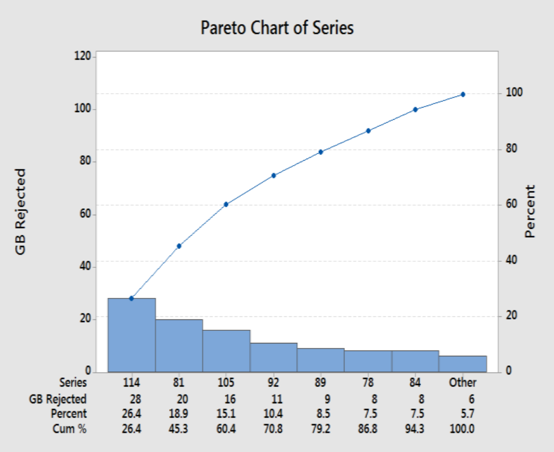

Fig 9: Pareto Chart for Modelwise rejections

Reason wise Rejections

Gear Box rejected for various reasons was summed up and a pareto analysis were made to arrive at the most frequent occurring cause for oil leakage. From this analysis we ranked the first five spots from where oil leakage occurs frequently. From this analysis we could target at that particular point in the assembly stage as these are the major reasons for oil leakage.

Reasons for rejections are ranked as follows:

1. IPS Cover Oil Leak
2. Idler Cover Oil Leak
3. Flange Side Oil Leak
4. Dummy Plug Oil Leak
5. Bell Housing Oil Leak

Table 3: Rejection details of Gear Boxes Reasonwise

Reasons for Rejection	GB Tested	GB Rejected
Bell Housing Oil Leak	60	4
Casing Oil Leak	6	1
Dummy Plug Oil Leak	247	16
Elbow Oil Leak	59	3
Flange Side Oil Leak	236	18
End Cover Oil Leak	150	12
Idler Cover Oil Leak	341	24
IPS Cover Oil Leak	399	28
PTO Oil Leak	54	4
Tower Oil Leak	81	6
Worm Gear Oil Leak	8	1

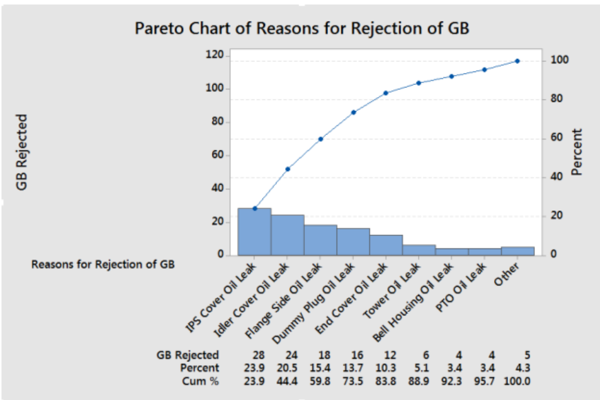

Fig 10: Pareto Chart for Reasonwise rejections.

Shift wise Rejection

Totally there are 3 shifts viz, First Shift, Day Shift, Night Shift. Gear Boxes tested and rejected in each shift were summed up and an analysis were made to find out in which shift most of the rejections are occurring. From the analysis found out that most of the rejections occur in the day shift and night shift.

Table 4 : Rejection details of Gear Boxes Shiftwise

Shift	GB Tested	GB Rejected	GB Rejected %
D/S	2597	39	1.31
N/S	2811	60	2.134
F/S	1672	21	1.255

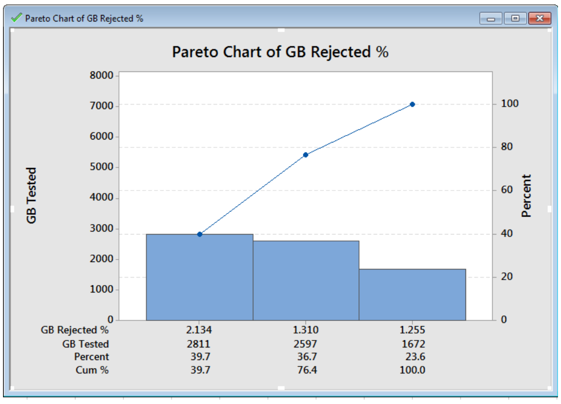

Fig 11: Pareto Chart for Shiftwise rejections.

As a result of analysis phase, our next step is to target the five reasons ranked, in the day shift and night shift, as these have the most frequency for oil leakage.

FishBone Diagram

Fishbone diagram for the various reasons of rejections ranked from pareto has been made. These are the potential causes which may lead to oil leakage in gear boxes. From these potential causes, root causes for the problem was arrived by monitoring the assembly process in the day shift and night shift.

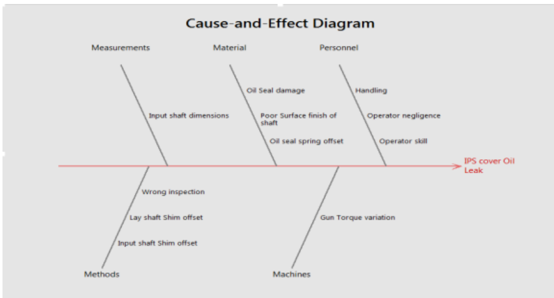

Fig 12: Cause and Effects for IPS cover oil leak

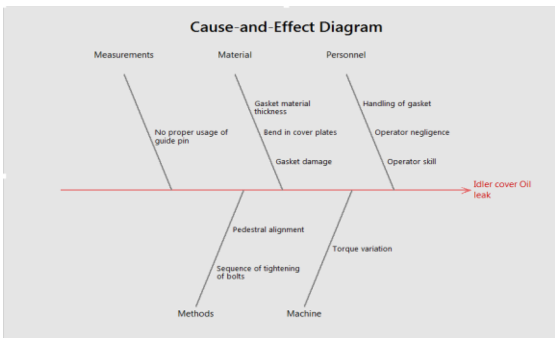

Fig 13: Cause and Effects for Idler cover oil leak.

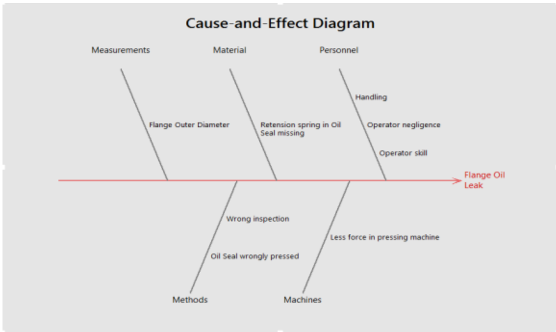

Fig 14: Cause and Effects for Flange oil leak

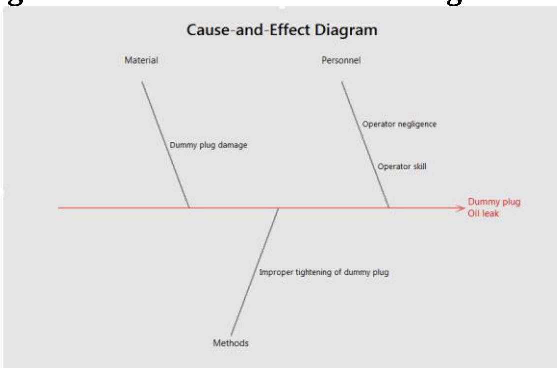

Fig 15: Cause and Effects for Dummy Plug oil leak

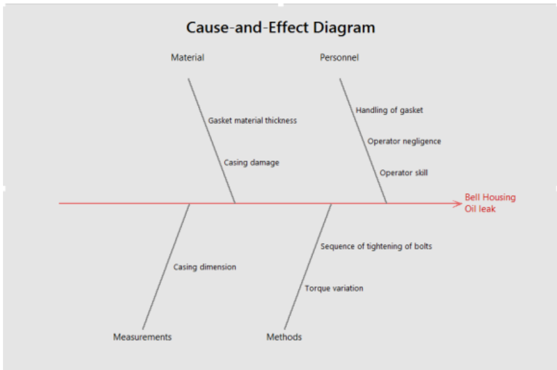

Fig 16: Cause and Effects for Bell Housing oil leak

ROOT CAUSES

When analysed with the Pareto and fish bone diagramthe root causes for the problems was determined. The causes for each of the problem is listed separately as shown below,

- **IPS COVER OIL LEAK**
  - No Oil seal

- Oil seal damage
- Lay shaft shim offset
- Input shaft shim offset

- **IDLER COVER OIL LEAK**
  - Bolt tightening
  - Gasket damage

- **FLANGE OIL LEAK**
  - Oil seal damage
  - Oil seal missing

- **DUMMY PLUG OIL LEAK**
  - Not fully tightened
  - Dummy plug missing

- **BELL HOUSING OIL LEAK**
  - Gasket shift

Phase 4 : Action

With the determination of the root causes for the problem the various possible solution to get rid of each cause is brainstormed by the implementation of which there can be an improvement in the through pass rate of the gearbox assembly line. They are shown in the list below,

Table 5: Causes and Solutions for Oil Leakage

Causes	Suggestions
No Oil Seal	Machine Modification
Oil Seal Damage	Guide Bush Modification
Lay Shaft Shim Offset	Instruction Sheet
Input Shaft Shim Offset	Instruction Sheet
Bolt tightening	Creating Operator awareness
Gasket Damage	Proper Gasket Storage
Gasket Shift	Guide Pin Modification
Dummy Plug Not Tightened	Instruction Sheet
Dummy Plug missing	Instruction Sheet

Phase 5: Check

The solutions given in the action phase was pilot implemented and 15 days gear box rejections data were collected, to check whether there is any change in the Through Pass Rate. By Hypothesis testing it was found that the TPR has improved. Therefore the next stage is to standardize the given solutions in the assembly process.

Phase 6: Standardize

The solutions given in the action phase were included in the assembly process and the solutions were standardized.

Phase 7: Conclude

Thus the Basic Problem Solving Methodology(BPS) has been adopted to increase the Through Pass Rate of the gear box assembly line. By increasing the through pass rate cost spent on reworking for a gear box has been reduced and the labour’s time has been saved. After pilot implementation of the suggestions, data was collected to verify improvement in through pass rate. A control Chart was plotted and it was found that every points were within the limits. This shows that the rejections has reduced.

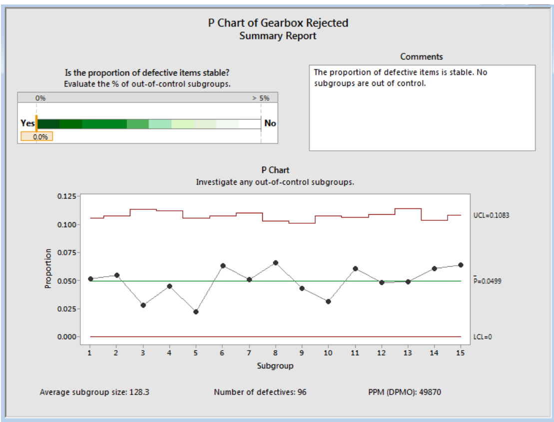

Fig 17: Control Chart after implementing the suggestions

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