To Reduce Setup Time For Engine Inside Test Cell Using "SMED" Concepts

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Abstract- *Engine performance and endurance test cells require great flexibility to meet customer demands. Hence Setup change time from one engine to another engine is a critical aspect of any engineering engine test cells. To demonstrate flexibility of the engine test cells lean manufacturing tools such as "Single Minute Exchange of Dies" (SMED) can be used to reduce total set-up change time. The total Setup change time can be defined as last engine removal to new engine cranked inside the test cell with desired data quality. The typical contents of engine setup change are engine removal, new engine mounting on supports, engine alignment with dyno, piping work etc.After completion of test of one particular engine, it is required to remove all the connections like Inlet & Exhaust piping, sensors & adapters fitment etc. and to make the new connections for next similar or different engine.*

The intent of this project is to reduce overall setup change time by following SMED guidelines. A standardize procedure is made considering maximum possible external activities (Outside the test cell) and minimum internal activities (Inside the test cell) from SMED concepts. There are four steps in SMED they are eliminate non value added activities, Separate internal and external activities, convert internal activities to external activity, reducing time for particular activity and to do maximum parallel activities. Considering above four steps standardize work instruction for engine setup change has been made and used for imparting training to the test cell engineers.

Keywords- Single Minute Exchange of Die, Engine Test Cell, Engine Testing

I. INTRODUCTION

An engine testing company has several Test Cells which can test variety of engines from 1L to 60L capacity. These Test Cells are broadly categorized as LHP (Light Horse Power), HMLD (Heavy Medium Light Duty) & HHP (High Horse Power) test cells. While installing the engines in the test cells installation team gives a schedule to complete the engine installation to the internal customer. Almost every time engine changeover setup time is missed by bigger margin due to various reasons and gap in the process.

Engine testing undergoes a significant amount of planning prior to the execution of the actual test.Various reasons for delay in the installation/removal are sometimes additional requirements are not mentioned by project manager in test plan, Cardan shaft bolts not matching, wrong fitting, Fuel adapter hose not available, blow by orifice not available, bellow, bend, hose, clamp not available, leakages issue in CAC & Heat Exchanger, Skid for engine mounting not available, no availability of manpower, Shims & bolts used for support modification during engine alignment not available.

Hence a standardize procedure has to be made which will be followed every time for installation & removal of engine along with various check sheets of pre-planning the engine and test cell readiness.

There are five teams which are responsible for engine installation/removal and the work done by them is shown below

- **Facility: -** Fabricate, joint intake, exhaust piping's & cooling system hoses, connect Charge Air Cooler unit with Heat exchanger etc. all type of plumbing work
- **Instrumentation: -** All types of sensors fitments, wiring work, air flow meter connections, CUTY & CALTERM file updating, electrical work etc.
- **Test operations: -** Engine mounting, engine alignment, coolant, oil filling, minipatch connection, and blow by connection etc.
- **Emission: -** Installation of various equipment's like smoke meter, gas analysers, DOC, SCR, DPF etc. on the exhaust line.
- **Pre-assembly area: -** Engine readiness, external activities, engine assembly, Kit box etc.

In order to meet planned vs actual time for engine installation above mentioned five departments should work as a team. Almost every time schedule attainment is missed by bigger margins due to various gaps in the process.

Lean manufacturing tools such as **"Single Minute Exchange of Dies"** can be used to eliminate waste of total set-up time for engine changeover.

1.1 Methodology

- Literature survey
- To study different types of engines to be installed in test cells
- Observe study and record various engine installation events, develop a mechanism for the same
- Process definition
- Setup time monitoring and action plan recommendations
- Bench marking study
- Identify gaps in the installation process
- Propose and implement solutions to reduce setup time using SMED concepts

II. LITERATURE SURVEY

Single-Minute Exchange of Die (**SMED**) is one of the many lean production methods for reducing waste in a manufacturing process. It provides a rapid and efficient way of converting a manufacturing process from running the current product to running the next product. This rapid changeover is the key to reduce production lot sizes and thereby improving flow. [6]

The phrase "single minute" does not mean that all changeovers and start-ups should take only *one* minute, but that they should take less than 10 minutes (in other words, "single-digit minute").Closely associated is a yet more difficult concept, **One-Touch Exchange of Die**, **(OTED)**, which says changeovers can and should take less than 100 seconds.

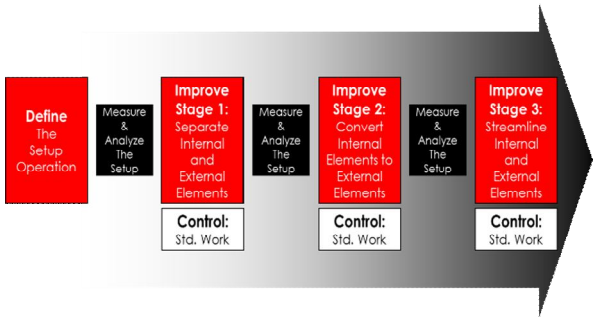

Figure 2.1: Block Diagram of SMED [8]

There are several basic steps for reducing changeover using the SMED system:

1. OBSERVE the current methodology and define setup instructions draft
2. Separate the INTERNAL and EXTERNAL activities. Internal activities are those that can only be performed when the process is stopped, while External activities can be done while the last batch is being produced, or once the next batch has started.

Figure 2.2: Distinguished Internal and external elements [8]

3. Convert (where possible) Internal activities into External ones

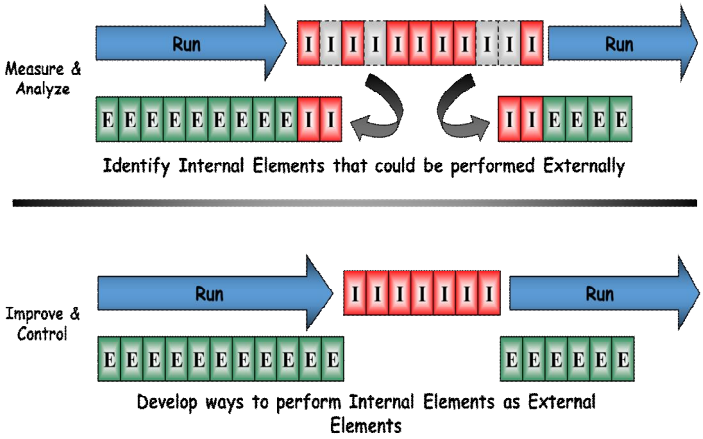

Figure 2.3: Converting internal activities to external activities [8]

Improve **Internal Elements** to further reduce downtime of the machine for Setup Operations

Improve **External Elements** to reduce Non-Value Added activities of the operator associated with the Setup

Examples of techniques that can be used to convert internal elements to external are:

- Prepare parts in advance (e.g. preheat dies in advance of the changeover)
- Use duplicate jigs (e.g. perform alignment and other adjustments in advance of the changeover)
- Modularize equipment (e.g. replace a printer instead of adjusting the print head so the printer can be configured for a new part number in advance of the changeover)
- Modify equipment (e.g. add guarding to enable safe cleaning while the process is running)

4. Stream line internal and external elements

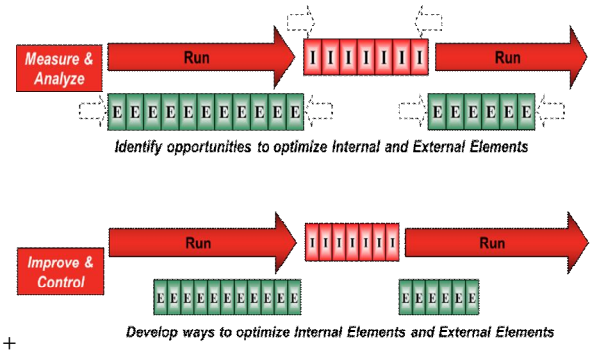

Figure 2.4: Optimize Internal and external elements [8]

Improve **Internal Elements** to further reduce downtime of the machine for Setup Operations

Improve **External Elements** to reduce Non-Value Added activities of the operator associated with the Setup

III. PROJECT APPROACH

Time study is often referred to as work measurement and it involves the techniques of establishing an allowed timed standard to perform a given task, with due allowance for fatigue and for personal and unavoidable delays. [20]

Methods of timing using Stopwatch:

There are two methods of timing using a stop watch. They are: Fly back or Snap back method and Continuous or Cumulative method.

➢ Fly back Method:

Here the stop watch is started at the beginning of the first element. At the end of the element the reading is noted in the study sheet. At the same time, the stop watch hand is snapped back to zero. This is done by pressing down the knob, immediately the knob is released. The hand starts moving from zero for timing the next element. Thus the timing for each element found is called observed time. This allows the element times to be entered directly on the time study sheet without the need for subtractions.

➢ Continuous method:

Here the stop watch is started at the beginning of the first element. The watch runs continuously throughout the study. At the end of each element the watch readings are recorded on the study sheet. The time for each element is calculated by successive subtraction. The final reading of the stop watch gives the total time known as observed time.

Setup changeover time for engine is defined as last engine removal to new engine cranked inside the test cell with desired data quality. In particular, this project is focused on reducing setup change time for R & D test cell. Research and Development test cell is far away different from the production test cell.

Installation of one engine differs from another in following ways

i. Engine Alignment method
ii. Cardan shaft, Eye plate, coupling, engine mounting brackets, Frame etc.
iii. Inlet & Exhaust piping components such as bends, clamps, bellows, sensor mounting position, Charged Air Cooler (CAC) Unit & Heat Exchanger, Chiller, hoses etc.
iv. Cooling system: - High temp & Low temp cooling system
v. Installation setup is different for Endurance and performance test cells
vi. Instrumentation sensor mountings & requirement of special sensors depends upon the type of test to be performed.
vii. Emission test setup if mentioned in test plan

To measure the actual time taken for engine changeover, time study is carried out. This time study gives the total details about all the activities performed during the engine change over. Time for each particular activity is noted down.

Initially in the month of January “Setup change operation monitoring” sheet was made in order to measure the actual time taken for each setup change inside the test cell. All the details about the Setup change over activities were provided in this sheet along with time taken for each individual activities.

Test cell operation monitoring sheet contains details about all the major activities, activity description, and time taken and also any remark/improvement needed for any particular activity is mentioned.

All the test cells during engine installation/removal were monitored whenever there is any new installation. Each and every details about the installation/removal were noted. Work carried out by various departments, time taken to complete certain activity, problems faced during installation were highlighted in the setup operation monitoring sheet.

This sheet is to be filled by operator whenever there is any new installation going inside the test cell. Twenty-four hours monitoring of installation/removal of engine is carried out. Every minute details about installation & removal is mentioned in this sheet.

Some of the problems discovered during the engine installation/removal are listed below

- Cardan shaft bolts not matching
- Fuel adapter not available
- Blow by orifice not available
- Bellow, bend, hose, clamp not available
- Leakages issue in CAC & HE
- Skid not available
- No manpower
- Sensor fitment not proper
- Shims, support modification during engine alignment not available
- Bolts used for support modification not available
- Bar used for alignment not available
- Heat exchanger secondary circuit choke up
- Waiting for engine
- Sensor malfunctioning
- Some special requirement regarding installation are not mentioned project manager in test plan

Some of the technical issues that leads to delay in installation are

- ACS/NTP (RH high/ low, low/high temp, low/high pressure, electrical and mechanical damage
- Air blower not working (Electrical and mechanical issues)
- Air filters (Choked/ high restriction)
- Air flow (High/low, air flow meter)
- Asset (Hang value not showing)
- CAC control circuit (Heat exchanger, 3-way control valve, Leslie valve)
- CBE (air & fuel leakages)
- Chiller (low/high temp, tripping)
- Coolant out temperature (high/low variation)
- Dyno controls issue (dyno controller, BME controller, drift)
- Emission bench error (Setup, hang, communication error, temp alarm)
- Engine parts unavailability
- FCU-fuel lock temp & pressure variation, air lock
- Overhead/unexpected/Unplanned activity
- SD coil (connections damaged, wiring replacing)

IV. IMPLEMENTING SMED

The objective of Setup Reduction is to dramatically shorten changeover or setup times. In engine installation/removal setup change time play a vital role. Hence it is necessary to reduce setup change time.

According to SMED concepts various steps are

Observe the current methodology

List down all the major activities that are performed inside the test cell from last engine removal to new engine installation. Study the current methodology for installation.

The total setup change time from engine removal to next engine installation is 79 Hours for HMLD engines and 139 Hours for HHP engines. This data is obtained from the month of May-Dec 2015.

In this procedure of engine removal/installation all the activities are done in series. Activities performed in series takes lot of time and are dependent activities. Unless and until if one department work is not finished other department will not start their work.

A complete procedure from removal to installation of engine which was practiced before is shown in table. It gives a complete structure of current methodology used before for installation/removal of engine. By carrying out detail analysis of each and every activity several non-value added activities can be eliminated. Also a complete changeover of processing activities can be done.

Separate Internal and External elements

Internal activities are the activities done when test cell is idle and external activities are those activities which are done when the last engine is running.In our case all the activities for engine installation/removal were done internally, no external activities were done when last engine was running.

Hence this was one of the reason for increased setup change over time.

Streamline internal and external activities

External activities are those activities which needs to be performed when last engine is running inside the test cell. The list of must do external activities is shown below.

- Arrange engine mounting supports & frame for next engine before last engine is stopped
- Eye plate and adapter plate has to be fitted on next engine before it comes to test cell
- Skid should be ready for the last engine being removed before that engine stops
- Suitable bend should be fitted on the turbocharger outlet side at engine pre-build area
- Functional check of equipment's such as CAC, HE, Expansion tank, Fuel conditioning unit etc. at regular intervals should be carried out
- Kitting box should contain all the required materials such as supports, clamps, nut, bolts, hoses required for installation
- Various sensors like oil pan sensor, coolant in & out adapter, oil gallery sensor, cylinder head sensor, exhaust manifold sensor etc. should be fitted on engine at pre-assembly area
- Tackles used for lifting engine should be brought in advance for removal of last engine and mounting of next engine
- For Palletised test cell leak test of CAC unit should be done outside the test cell.

Standardize Procedure for Installation and Removal

In order to reduce time all the departments have to work parallel. Engine installation/removal process is a dependent work process. Certain activities have to be completed before starting next activities.

During engine installation almost 60% of work is of facility department. Hence it is necessary that when facility team is working inside the test cell other teams should do maximum parallel work. By observing and analysing the installation/removal of engine inside the test cell several parallel activities can be done are shown below in table.

ENGINE REMOVAL		
Operations	Facility	Instrumentation
Waiting for engine to cool down		
Close fuel valve		
Close raw water supply valves		
Engine intake / exhaust, fuel connection closing	Remove heat insulation sheets	
Movement of coolant removal drum & pump from store area to test cell		Disconnect sensor connections from engine and piping & removal of sensors
Draining of coolant in container		
Remove fuel connections	Disconnect & remove HE & CAC unit	
Remove the Blowby measure tool	Remove adapter plate & cardan shaft	
Remove minipatch connection	Disconnect Exhaust, intake pipes	
Arrange the right skid & inform Shift incharge to arrange for fork lift		
Remove the excess material from test cell (Do 5S)	Remove the excess material from test cell (Do 5S)	Remove the excess material from test cell (Do 5S)
Unmount engine from supports & lift the engine by crane		
Remove the engine assembly from test cell	Remove the supports, dyno etc.	

In the newly developed procedure made using SMED concepts, all the departments involved in installation/removal can work together parallel. Due to parallel activities the total time taken for engine changeover will be minimum than before. If each and every step of newly developed procedure is followed for installation of engine, then there will be 30 % reduction in setup change time.

ENGINE INSTALLATION		
Operations	Facility	Instrumentation
	Bring the engine from Build up area to test cell	
Pre-installation review		
	Engine movement from skid to test cell	
Mount engine on supports at Front & Rear end		Asset file updatation & Cuty file updatation
	Get/Fabricate the pipes of appropriate diameter from fabshop	
	Connect engine with cardan shaft	
Alignment of engine with Dyno is carried out with Dial guage indicator Laser beam or water tube		
Connect FCU, FMU with fuel supply unit[Mostly pipes are ready almost flexible]	**Exhaust Line fitment**	
Fit the blowby orifice a proper location with right orifice size as per test plan	Connect bend & bellow	
Mini patch connection [For filtering oil from wear & tear of mating parts]	Check the layout of exhaust pipe & Select pipe of suitable diameter & connect pipe from bellow to main exhaust oulet	
Mount shutdown coil on the engine & connect it with throttle connection	Mount exhaust brake at correct location as per test plan	Install turbo inlet and outlet pressure & temperature sensors at drilled surface provided
Emission system installment	**Air intake system**	
As per requirement any external devices (Cat-Con, DOC, SCR) are to be attached suitable arrangements are to be made for installation of devices, piping requirements and sensors	Connect pipes from Compressor inlet to Air intake system (Compressor Inlet-Intake brake-air cleaner assembly- hotbox-atmosphere)	
	Mount the intake brake before air filter in air intake system	Mount various pressure & temp sensors at proper location on intake system
	CAC-Heat exhanger fitment	Install air flow meter if mentioned in the test plan
	CAC,HE is brought inside test cell	Check Intake brake connection are working properly or not
	Connect pipes from engine compressor outlet to CAC unit inlet(This pipes are larger in size than raw water pipes)	
	Connect pipes from CAC outlet to Engine intake	
	Connect pipes from HE to CAC for raw water connection	
	One inlet & outlet Raw water connection is provided to HE from basement for cooling purpose	Siemens valve functional check done
	Additional work such as connection of HE with coolant tank etc	Mount various pressure & temp sensors at proper location on CAC unit
	Coolant circuit	Various flow meter check done
	Connect raw water hoses from basement to engine for coolant in and out connection	
	Check on requirement of functional or block open thermostat as per test plan	Mount sensors & transducers at proper location to measure Coolant pressure and temperature
Connect fuel return line to heat exchanger(Depending upon test cell)	Connect primary heat exchanger with secondary heat exchanger	Cable tie up[hoses, harness proper tie up]
Coolant vent connection & coolant filling	CAC leak test	Check whether all the pressure hoses and wires does not come into contact with the hot surfaces
Fill the oil as per specification in test plan	Exhaust leak test	Coolant valves, IMT valves connection done & check
	Intake Leak test	
	Cover Intake & Exhaust piping with heat shield	
	Check for oil, coolant, fuel , water leakages	
Installation review[F,O,I,PM]		
open points are closed		
Engine ready for cranking		

IV.I Spaghetti diagram

A Spaghetti diagram is a visual representation of the operators' movements during a given period of time, in this case during a changeover. It is a very effective tool for observing waste within an activity, most commonly transportation and movement waste.

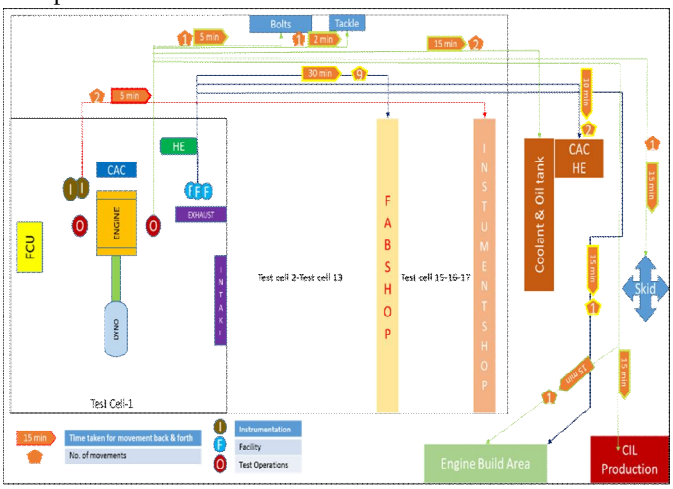

Figure 4.5: Spaghetti diagram of TC

As shown in spaghetti diagram time taken movements of various people from facility, instrumentation and operations department are illustrated above. Time taken for each particular activity is mentioned in the table below.

The exact timing for various activities were monitored in approximately 10-15 iterations. A detail time measurement analysis was carried out of the people during installation/removal of engine. This activity gives the actual distance travel by various persons involved in the installation for multiple purposes. Easy access to all the materials should be provided to the persons involved in the installation.

The figure 4.7 clearly states that more than 1 hour is wasted to bring some or the other material outside the test cell. During installation & removal of engine approximately 60 minutes is taken by various persons to bring necessary accessories.

V. BENCHMARKING STUDY

Exhaust system

Company Practices

- Rigid pipes are used everywhere
- Layout of exhaust pipe is not available & location exhaust brake is not fixed

Best Practices

- Bend can be connected to turbo & Bellow can be eliminated from the system
- Flexible piping is connected to the bend covering maximum portion (length) of pipe
- Instead of flanges V-band piping can be used. Another advantage of V-band piping if used in exhaust line weight on turbocharger reduces.
- Emission system & Exhaust brake can be installed after completion of flexible pipe

Instrumentation

- Various colour coding for pressure sensing pipes can be done. Hence at instrument cluster it would be easy to identify and match the connection of same colour. At our engine testing facility test cell labelling of each sensors are done. This tagging of the sensor allows easy access to find it's mating part. One can easily identify different temperature sensors of exhaust, intake, coolant, fuel and oil etc.

CAC unit assembly & leak test

Company practices

- Rigid piping's are used everywhere
- Leak test is done inside test cell
- Heat exchanger is required to cool the engine

Best practices

- Flexible hoses can be connected between two rigid pipes at both sides of CAC In & compressor out also CAC & Engine intake
- Sensors are mounted on rigid pipes connected to CAC unit
- Leak are very rarely found as no weld joints are provided in the system

Engine mounting

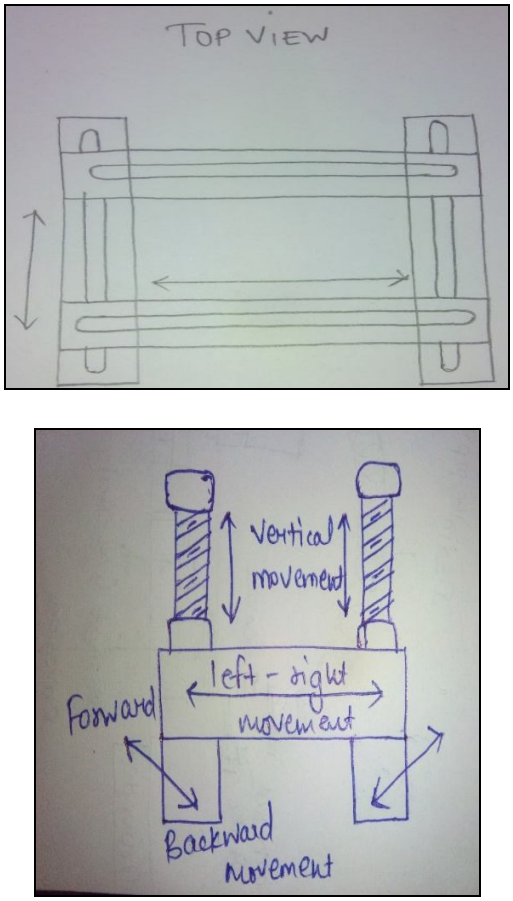

Figure 5.6: Best Practices

Company Practices

- For engine alignment with dyno, water tube method, Dial indicator or laser beam method is used
- To match engine alignment with dyno large size bolts, shims are needed also sometimes we need to change position of front & rear supports due to trial & error method of mounting engine on frame.

Best practices

- Here engine is to be mounted on 4 screw jacks. Three movement of engine are possible two horizontal & one verticals. Vertical movement is possible by adjusting height of screw jack.
- Because of three movements of engine, adjustment of engine after alignmenttakes very less time. There is no need of adjusting engine supports or to change bolts of supports.

VI. FINDINGS

After applying SMED guidelines and Benchmarking study various loopholes in the process was founded.

Kitting Plan

Various Set up change items (tools, accessories, spares etc.) - Installation, Facility and Instrumentation is made available in the kitting box. Kitting box is prepared at pre-assembly area prior to installation of the new engine.

All the parts, materials required for engine installation are mentioned in the sheet. The kitting box is prepared by skilled person working at pre-assembly area. The instrumentation kitting box is prepared well in advance after test plan for the given engine is known. Types of sensors, adapters, RTDs, wiring harness are provided in the instrumentation kit box. Even extra pair of calibrated sensors is provided in the kit in case of damage to any sensor or failure of that sensor.

Engine Hand Off/Pre-Installation Review/Engine Receipt at Test Cell

A sign off is done by operator, instrumentation person, facility person, project manager & shift in charge on test cell floor whenever new engine arrives in the test cell. All the special requirements of project manager regarding installation is considered. Also Schedule attainment of new engine installation is made at that point of time. Planned time is given by all the teams for new engine installation. All the teams have to finish their work before deadline. A copy of schedule attainment will be displayed on the test cell door. So each and every people will be aware of the time in which they have to complete their particular work.

This practice has been started for every new engine coming on test cell floor for installation from the month of February. In presence of project manager all the teams (Facility, Instrumentation, Operator, emissions, controls etc.) will give their planned time as per requirement of test cell setup. After completion of test cell setup if any changes are to be made from project manager side then it will not be entertained. Once test cell setup for new engine is finish no changes in the installation will be done afterwards. This practice of pre-installation review saves lots of time, prevents unnecessary delay due to improper communication. During the pilot implementation of project inside the test cell all the check sheets were duly filled.

Pre-installation check list

During removal of engine many a times accessories required was not available. During removal operations person has to look out for skid, siling etc. Hence to keep this thing ready, a checklist was made which contains list of all the accessories required for removal and installation. Operations person has to fill this sheet one day prior to engine removal so it is ensured that time is not wasted to find out such things. A format of pre-installation check sheet is shown below.

Once the removal confirmation comes from the project manager side, Pre-installation check sheet has to be filled. Suppose if any of the accessories is not available while filling pre-installation check sheet than immediately shift in charge has to be informed about the unavailable items. The shift in charge has too arrange the unavailable items before the removal of last engine begin. During pilot implementation of project all the check sheets were filled and adherence to the process was monitored continuously for all the removal of engines.

Design of Exhaust System Piping Layouts

Design of exhaust system layouts has been made for HHP engine describing exhaust brake position, sensors and adapter mountings positions. These layout is given to facility team prior to installation so that it will be easy for them to identify piping components also if nor available they can fabricate it.

During the pilot implementation period from 28 March-7 May there were many installations piloted. Out of which installations at TC-11 and TC-9 took the lowest time for installation. TC-11 is an HHP engine Test cell while TC-9 is HMLD engine test cell.

We decided to consider the time slot of fifteen minutes for taking observations. Every activity is recorded for these fifteen minutes. We used fly back method of time study. After every fifteen minutes, stopwatch is snapped back to zero.

Sectional data analysis for removal and installation of engine at TC-9 is shown in table below

Table 7.1: Detail analysis of Removal/Installation at TC-9

ENGINE CHANGEOVER IN TEST CELL 9					
S.no	Date	Start time	End time	Activity	Remark
1	02-05-2016	12.00pm		Engine stopped & changeover started	
2	02-05-2016	12.00 pm	13.15 pm	Waiting for engine to cool down	
3	02-05-2016	13.15 pm	13.30 pm	Fuel valve & raw water supply valve closed	
4	02-05-2016	13.30 pm	14.00 pm	Oil sample collected after test	
5	02-05-2016	14.00 pm	14.15 pm	Heat insulation sheetd removed	
6	02-05-2016	14.15 pm	14.30 pm	No work	Tea break
7	02-05-2016	14.30 pm	14.45 pm	No work	
8	02-05-2016	14.45 pm	15.00 pm	Coolant removal pump brought from storage area to test cell	
9	02-05-2016	15.00 pm	15.30 pm	Coolant draining	
10	02-05-2016	15.30 pm	15.45 pm	Fuel line removed	
11	02-05-2016	15.45 pm	16.15 pm	No work	Facility team busy in other test cell
12	02-05-2016	16.15 pm	16.30 pm	Instrumentation removal	
13	02-05-2016	16.30 pm	16.45 pm	Minipatch connection removed	
14	02-05-2016	16.45 pm	17.00 pm	Blowby connection removed	
15	02-05-2016	17.00 pm	17.30 pm	Exhaust piping removal	
16	02-05-2016	17.30 pm	18.00 pm	Engine intake & CAC connection removed	
17	02-05-2016	18.00 pm	18.15 pm	CAC & HE moved out of TC to storage area	
18	02-05-2016	18.15 pm	18.30 pm	Cardan shaft removal	Removing bolts
19	02-05-2016	18.30 pm	18.45 pm	Cardan shaft removal	Bolts removed
20	02-05-2016	18.45 pm	19.00 pm	Coolant In & Out pipe removed	
21	02-05-2016	19.00 pm	19.15 pm	Excess material from TC removed	5S done
22	02-05-2016	19.15 pm	19.45 pm	Cleaning the test cell	Housekeeping
23	02-05-2016	19.45 pm	20.45 pm	No work	Dinner
24	02-05-2016	20.45 pm	21.00 pm	Shift incharge informed to bring forklift	
25	02-05-2016	21.00 pm	21.15 pm	Engine unmounted from supports	
26	02-05-2016	21.15 pm	21.30 pm	Engine lifted by crane	
27	02-05-2016	21.30 pm	21.45 pm	Engine mounted on skid	
28	02-05-2016	21.45 pm	22.00 pm	Engine removed out of test cell	
29	02-05-2016	22.00 pm	22.15 pm	Supports of last engine removed and stored at proper place	
30	02-05-2016	22.15 pm	22.30 pm	Next engine brought to TC corridor	
31	03-05-2016	22.30 pm	00.45 am	No work	Facility team busy in other test cell
32	03-05-2016	00.45 am	02.00 am	Test cell conversion- Supports changed for new engine	
33	03-05-2016	02.00 am	02.30 am	Engine brought inside TC by crane & mounted on supports	
34	03-05-2016	02.30 am	04.00 am	Engine alignment completed	With Dial guage indicator
35	03-05-2016	4.00 am	4.15 am	Fuel in connection done	
36	03-05-2016	04.15 am	07.15 am	Exhaust connection done	
37	03-05-2016			Intake connection done	
38	03-05-2016			Coolant connection in progress	
39	03-05-2016	07.15 am	07.30 am	No work	
40	03-05-2016	07.30 am	07.45 am	Blow by connection done	
41	03-05-2016	07.45 am	08.00 am	No work	Breakfast
42	03-05-2016	08.00 am	08.15 am	Coolant vent connection done	
43	03-05-2016	08.15 am	08.45 am	Oil drained from engine	
44	03-05-2016	08.45 am	09.15 am	Air compressor back plate fitted	
45	03-05-2016	09.15 am	09.30 am	Radiator fan bolt changed	
46	03-05-2016	09.30 am	10.30 am	Oil measurement setup done	
47	03-05-2016	10.30 am	11.15 am	Coolant out modification in progress	
48	03-05-2016	11.15 am	12.15 pm	No work	Lunch
49	03-05-2016	12.15 pm	14.00 pm	CAC leak test in progress, Coolant out modification done	
50	03-05-2016	14.00 pm	14.15 pm	No work	Tea break
51	03-05-2016	14.15 pm	15.00 pm	No work	Facility team busy in other test cell
52	03-05-2016	15.00 pm	16.00 pm	Coolant in modification in progress	
53	03-05-2016	16.00 pm	19.30 pm	Calterm & Cuty file updation	
54	03-05-2016	19.30 pm	20.00 pm	Instrumentation hook up started	
55	03-05-2016	20.00 pm	20.45 pm	No work	Dinner
56	03-05-2016	20.45 pm	23.00 pm	Instrumentation hook up in progress	
57	03-05-2016	23.00 pm	12.30 am	leak check in progress	
58	04-05-2016	12.30 am	02.00 am	Instrumentation hook up completed	
59	04-05-2016	02.00 am	02.30 am	leak check completed	
60	04-05-2016	02.30 am	03.30 am	Facility time taken to close open points	
61	04-05-2016	03.30 am	04.30 am	Test ops time taken to close open points	
62	04-05-2016	04.30 am	06.00 am	Oil filling & coolant filling	
63	04-05-2016	06.00 am	07.30 am	Working on engine (Coolant,oil,urea filling & other connections)	
64	04-05-2016	07.30 am	08.30 am	Controls hook up	
65	04-05-2016	08.30 am	09.45 am	No work	Operator busy in other test cell
66	04-05-2016	09.45 am	11.45 am	Controls hook up	
67	04-05-2016	11.45 am	13.00 pm	Installation review	
68	04-05-2016	13.00 pm	13.30 pm	No work	Lunch
69	04-05-2016	13.30 pm	14.45 pm	Supports given to compressor out pipe	
70	04-05-2016	14.45 pm	17.00 pm	Working on Oil drain set up	
71	04-05-2016	17.00 pm	18.15 pm	Test Ops: time taken to close open points	
72	04-05-2016	18.15 pm	19.45 pm	Instrumentation: time taken to close open points	
73	04-05-2016	19.45 pm		Engine cranked for check up	

For the installation/removal at TC-9 all the activities mentioned above in table 6.1- 6.5 were followed. The kitting box was ready for the next engine at TC-9 before the last engine removal started. One day before removal of last engine at TC-9 pre-installation check sheet shown in Table 6.4 was filled and checked. The pre-installation review (Table 6.3) was done for the new engine on test cell corridor. All the teams (Project manager, Instrumentation, Facility, Operations etc.) discussed about the installation requirement according to test plan.

ACTIVITIES	Time(min)
Last Engine removal from test cell	600
Supports mounting inside the TC and eye plate fitted on engine	180
Pre-Installation review	30
Engine mounted on supports	30
Engine alignment with dyno	90
Facility hook up- Exhaust, Intake and water connection done	180
Engine assembly Blow by connection done Vent connection done Oil drained Air compressor back plate fitment Fan bolt changed	135
CAC leak check in prog (off line) Coolant in & out modification done	180
Instrumentation hook up	385
Leak check	105
Engine assembly-Oil drain setup	195
Controls hook up	120
Test Operations	165
No work due to no manpower	225
No work (Meal, Dinner, tea break)	210
Facility: time taken to close open points	265
Instrumentation: time taken to close open points	180
Installation review	75
Total time in minutes	3350
Total time in Hours	55.8

The above table shows the events done by different departments with its respective timing. The departments are Facility, operations, emissions and instrumentation and control. Their respective time taken for engine change over process is noted down with the help of time study.

All the activities mentioned in the process planning and implementation were adhered. The pilot implementation of engine installation and removal were done according to standardize procedure given in Table 4.7. Although the standardize procedure was not fully adhered due to some issues but around 70%-80% it was followed perfectly.

VII. CONCLUSION

Time study for a particular test cell has been done in order to demonstrate the standardize procedure for installation/removal of engine inside the test cell. HHP and HMLD engines installation/removal were undertaken using standardize procedure vide SMED guidelines. Various process improvements such as Usage of V-band pipe, preparation of kitting box, conformity of various check sheet parameters, Pre-installation review of each incoming engine were incorporated for pilot implementation of project. All the pre-requisites for removal/installation of engine were arranged prior to actual testing of engine. Necessary modifications have been done for the improvement in Test cell setup from the study of benchmarked test cell. This standardize procedure for installation/removal can be deployed to all other test cells horizontally.

Implementation of aforesaid processes yields 30 % reduction in engine changeover setup time, which indicates conformity of objective of the project. The time taken after pilot implementation of project is 94.5 Hours for HHP engine test cell and 55.8 for HMLD engine test cell.

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