Industrial Case-study Report

On Slurry Cartridge Explosives at Solar Industries India Limited

This report is submitted in partial fulfillment of the requirements of Sixth semester B.E. in Mechanical Engineering.

Submitted By

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CERTIFICATE

This is to certify that **Ishaan Tiwari** has completed the Industrial Case-study on **Slurry Cartridge Explosives** at **Solar Industries India Limited** in partial fulfillment of the requirements of Sixth semester B.E. in Mechanical Engineering at R.C.O.E.M., Nagpur during academic session 2015-16.

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ABSTRACT

Solar Industries India Limited is one of the leading explosives manufacturers in the world. It manufactures various explosive products for industries in mining and defence sector. The base product of the industry is slurry explosive cartridge. The following industrial case study has been carried out at one of its plants in Chakdoh, Bazargaon. The aim of this study is to identify the problems faced by the industry and provide plausible solutions that can, in any way, alleviate those obstacles. The study has been carried out in Process Plant 1 of the industry which produces slurry cartridges of various sizes. In the following report some problems pertaining to the production of slurry explosive cartridges have been identified and solutions have been proposed. These methodologies, if incorporated, can bring about substantially efficient changes in the production.

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1. Introduction

1.1 About the Industry

Solar Industries India Limited is a manufacturer, supplier and exporter of industrial explosives and initiating systems. Its registered and corporate office is at 11 Zade Layout, Bharat Nagar, Nagpur-33. One of the plants is at Chakdoh, Tehsil Katol, Dist& City Nagpur. Solar Explosives Limited was founded in 1995 by its founder Chairman Shri Satyanarayan Nandlal Nuwal to produce cartridge explosives. Today, under the name Solar Industries India Ltd. (SIIL), the company has grown to become India's largest manufacturer of Industrial explosives and Explosive initiating systems and spreading its presence to Global Markets.

Solar headquartered at Nagpur offers high-quality products and services that are backed by stringent safety standards, a robust infrastructure, and a proven quality management system. The company supports major mining & infrastructure companies including the recognized names like Coal India Limited, Vedanta, Tata, Jindal, SAIL, L&T, Anglo Gold and many more.

Solar's manufacturing facilities span 16 locations across India along with 2 manufacturing units in Africa. Further efforts to establish a manufacturing facility to cater Europe is presently underway.

Solar Industries India Ltd. is driven to meet its client and stakeholder's expectations by providing blasting solutions that align with each company's requirements. Solar continually pursues improvement in quality and safety by holding internal benchmarks even higher than its customer's own expectations and by operating as if it were its own competition. This, in turn, drives process improvement, system innovations, and employee advancements.

Figure 1: Industry View - Solar Industries India Limited

The Chakdoh plant spans over 370 acres with 30 operational process plants and 4 upcoming plants. The production capacity of the plant is 500 metric tonnes per day. It employs a total workman force of 1200, plus additional staff of 400.

Certifications and Accreditations

Plant is certified for ISO 9001:2000; ISO 14001:2004 and OHSAS 18001:2007. It has 'CE' certification for exports into the European Countries awarded by CAPEXIL for export achievements in 2011. The company undergoes ISO audit every year and certification audit every 3 years.

Products Manufactured

1. HMX:HMX, also called **octogen**, is a powerful and relatively insensitive nitroamine high explosive, chemically related to RDX. Like RDX, the compound's name is the subject of much speculation, having been variously listed as High Melting explosive, Her Majesty's explosive, High-velocity Military explosive, or High-Molecular-weight rdx
2. PETN: **Pentaerythritol Tetranitrate** as PENT, PENTA, TEN, corpent, penthrite. PETN is one of the most powerful explosive materials known, with a relative effectiveness factor of 1.66.When mixed with a plasticizer, PETN forms a plastic explosive. As a mixture with RDX and other minor additives, it forms another plastic explosive called Semtex

3. TNT(**Trinitrotoluene**):This yellow-colour solid is sometimes used as a reagent in chemical synthesis, but it is best known as an explosive material with convenient handling properties. The explosive yield of TNT is considered to be the standard measure of bombs and other explosives. In chemistry, TNT is used to generate charge transfer salts.
4. Slurry Explosive: This is the base product of the industry. It is a fuel sensitized explosive mixture consisting of an aqueous ammonium nitrate solution that acts as the oxidizer.

5. Detonators: A **detonator** is a device used to trigger an explosive device. Detonators can be chemically, mechanically, or electrically initiated, the latter two being the most common.

   The commercial use of explosives uses electrical detonators or the capped fuse which is a length of safety fuse to which an ordinary detonator has been crimped. Many detonators' primary explosive is a material called ASA compound. This compound is formed from leadazide, lead styphnate and aluminium and is pressed into place above the base charge, usually TNT or tetryl in military detonators and PETN in commercial detonators.

6. Detonator Fuse: In an explosive, pyrotechnic device, or military munition, a **fuse** (or **fuze**) is the part of the device that initiates function. In common usage, the word fuse is used indiscriminately.

7. Boosters: An **explosive booster** is a sensitive **explosive** charge that acts as a bridge between a (relatively weak) conventional detonator and a low-sensitivity (but typically high-energy) **explosive** such as TNT.

Clients/Customers

Solar Industries manufactures explosives primarily for mining and exploration industries. Some of its customers are

1. Coal India
2. Hindustan Zinc
3. Reliance Industries
4. Defence Sector; Ordnance Factories
5. Mining & Oil Exploration Industries

Departments:

The company is divided into the following departments

1. Production
2. Quality Control
3. Research and Development
4. Safety Department
5. Administration
6. Dispatch
7. Marketing
8. Maintenance

1.2 Slurry Explosive Cartridge

The slurry cartridge explosive is the base product of Solar Industries India Limited. Production of this explosive takes place in 4 of the 30 process plants present at Chakdoh.

Composition:
The slurry comprises a mixture of dry fuel powder and oxidizer blend.

The dry fuel composition involves a mixture sulphur, starch and aluminium, which is heated to a maximum temperature of 42^{o}C in a blender. The oxygen level during the process is kept at less than 8%.

Ammonium Nitrate is melted at 70^{o}C and to it Guar Gum (0.1%), MEG and water are added to constitute the oxidizer blend for the slurry.

The slurry constitutes approximately 14% dry fuel and 86% percent oxidizer blend.

The cartridges are made in the following various sizes specified by their diameters-

1. 25mm
2. 83mm
3. 200 mm

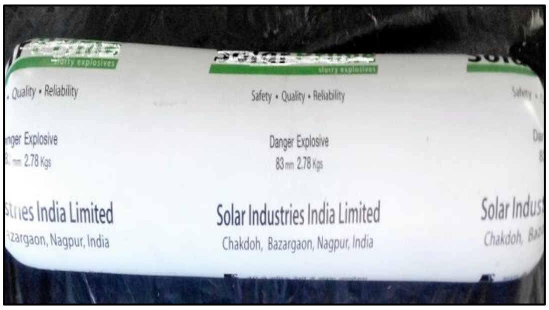

Figure 2: Cartridge Sample

1.3 Plant Layout – Process Plant 1

The following is the layout of process plant 1 that has been producing slurry cartridges at Chakdoh, for the past 20 years.

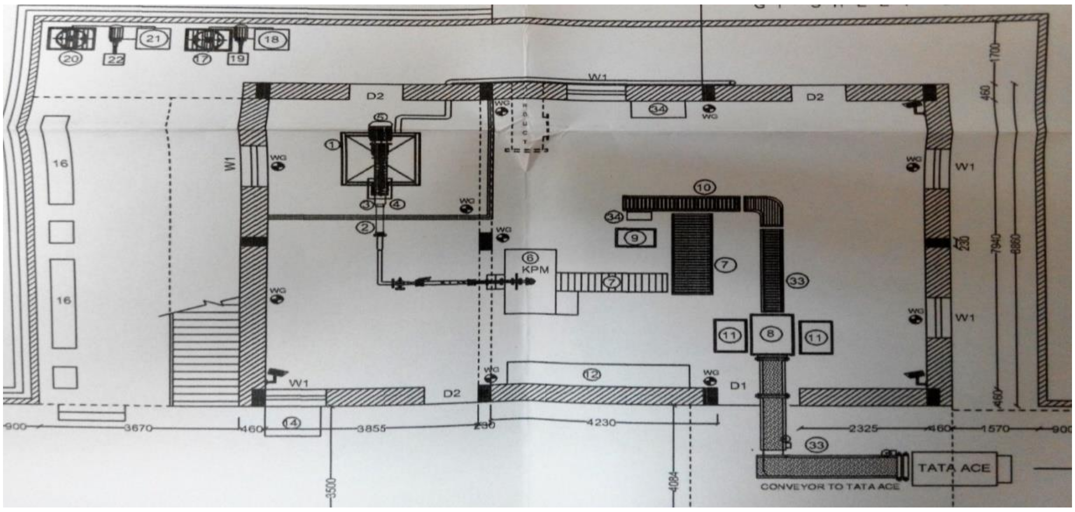

Figure 3: Plant Layout

The section labelled ① is the hopper which accommodates about 1 tonne of dry fuel powder. Dry fuel, 3 tote bins full, of 330 kg each, is dumped into the hopper using a crane from the top of the plant. From the hopper, the powder is driven into the dynamic mixer ③ by a screw conveyor at a rate of 13.7 kg/min. The screw conveyor is driven by 2HP motor running at 1450 RPM, labelled ⑤. Its speed is controllably reduced by a gear box with a gear ration of 1:30.9. The dynamic mixer is where the oxidizer blend, pumped from a tank outside at 86.3 kg/min, mixes with the powder and the slurry is formed. The slurry is pumped from the mixer using a special pump ② to the cartridge packing machine KPM ⑥.

Figure 4: Cartridge Packing Machine

The KPM machine packs the slurry using a plastic film and drops the cartridges onto the conveyor ⑦ at a rate of 36cartridges/min. The conveyor takes the cartridges to⑩ where 9 cartridges are accommodated per carton. The carton is then conveyed to section ⑧ where it is weighed to meet the target of 25.02 kg. After weighing, the cartons are sealed and then dispatched.

Figure 5: Conveyor system for carrying cartons

The entire process parameters are controlled using a PLC controller. The man limit of the plant is 14 at any given time, and the process involves 5-6 labourers.

Figure 6: Carton ready to dispatch

2. Literature Review:

Impact Plate Flowmeter is a simple and precise, yet low cost solution for calculating time based consumption of material through a continuous process. This flowmeter can be used to measure flow rate of powder, granules and even piece parts under free flow. It is used where space is at a premium. Its simplicity of installation makes its similarly convenient for retrofit applications where enhanced monitoring facilities are required. It is simple to integrate in vertical process, has high accuracy due to discreet weighments and continuous and intermittent operation.

Telescopic Conveyer Telescopic belt conveyors are multi functional devices which are used in many different areas for carrying products, mainly in loading of parcels and all kind of sags, bales etc. on vehicles (loading and unloading of vans, trucks and articulated lorries serially). Loading and unloading operations can be very easily and advantageously performed by system's extension and retraction parts which can move forward and reverse. Conveyor system can be used in both delivery exit and storage yard entry, because conveyor system has both forward and reverse working principle. Usually conveyor extends and enters completely into the vehicle which will make delivery by the help of approaching truck and articulated lorry. After loading is completed, conveyor retracts and empties area telescopically. Altough system's extension and retraction is between specific standard dimensions, different body length and extension dimensions can be presented and conveyor can be produced single- stage or multi-stage.

3. Identification of Issues /Problems:

a. Inaccurate measurement of mass flow rate of dry fuel while mixing with solvent.
b. Unloading of Ammonium Nitrate and carrying it to the storage area is manual and time consuming.
c. Transporting of dry fuel from blenders to the process plant is done using tote bins impelled by labourers.
d. Weighing of the carton is done at the last stage of the assembly line. In case the target weight of 25.02 kg is not met, all the cartridges are taken out and then re-arranged by trial and error. This consumes a lot of time and labour.

4. Methodology

Problem 1: Inaccurate measurement of mass flow rate of dry fuel while mixing with solvent.

Present Scenario:

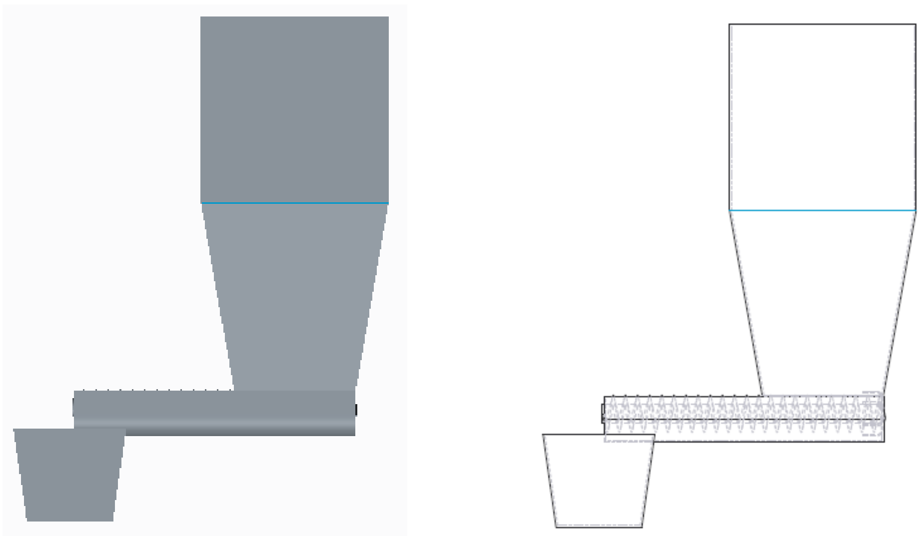

Figure 7: CREO model of Screw Conveyor Setup

As shown in figure, the setup comprises of hopper in which the dry fuel (powder) is stored and it comes down to the screw conveyer which is pushed to another hopper for dynamic mixing. The dynamic mixer mixes the dry fuel and solvent, solvent which is conveyed through pipes in the hopper. It is then pumped into the cartridge packing machine. The slurry is packed in a film wherein one cartridge weighs 2.78kg and one carton consists of 9 such cartridges. The carton is then packed and weighed at the end of the process and is ready to dispatch.

Proposed Methodology:

Impact type Flowmeter is employed by replacing the screw conveyer setup.

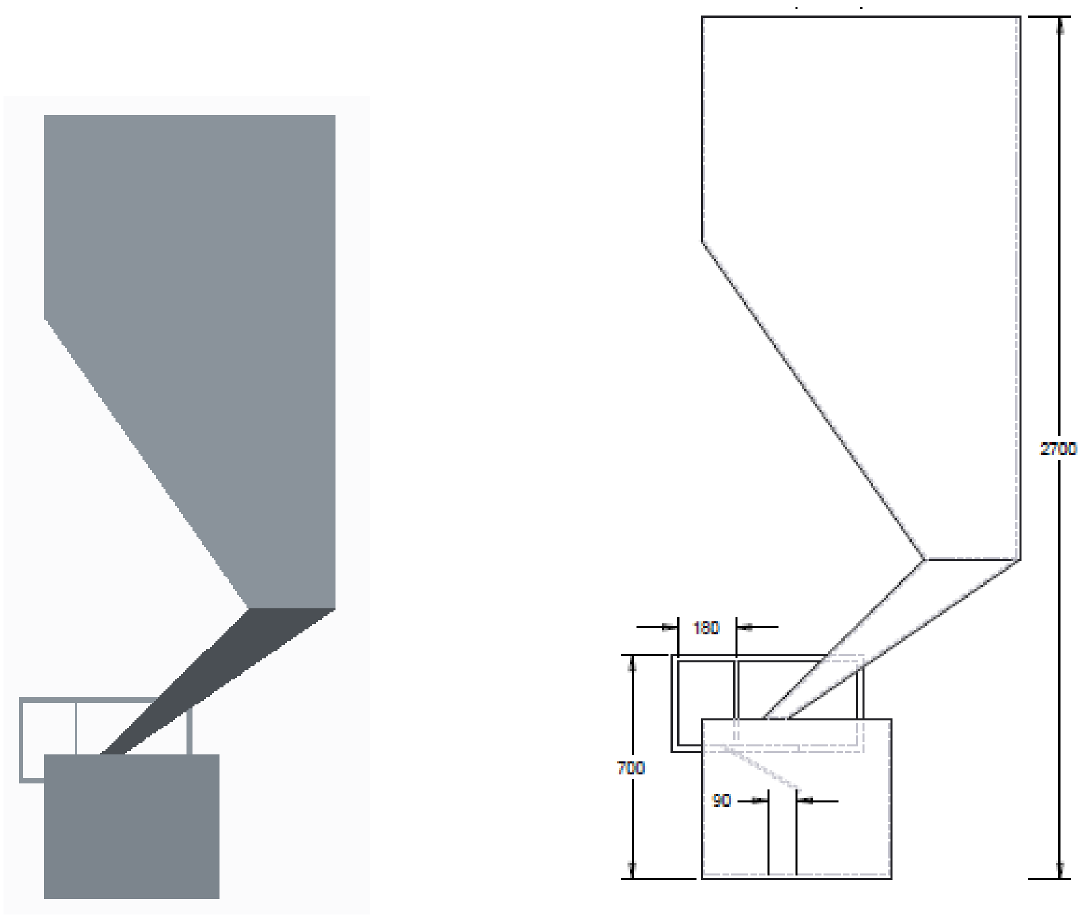

Figure 8: CREO model of modified Impact Plate Flowmeter setup

<u>Working:</u>

An impact plate at an angle of 60 deg is placed below the hopper opening at a minimum distance of 15mm from the hopper. This impact plate consists of a Wire Embedded Load Cell on the other side. The dry fuel falls on the impact plate as shown.

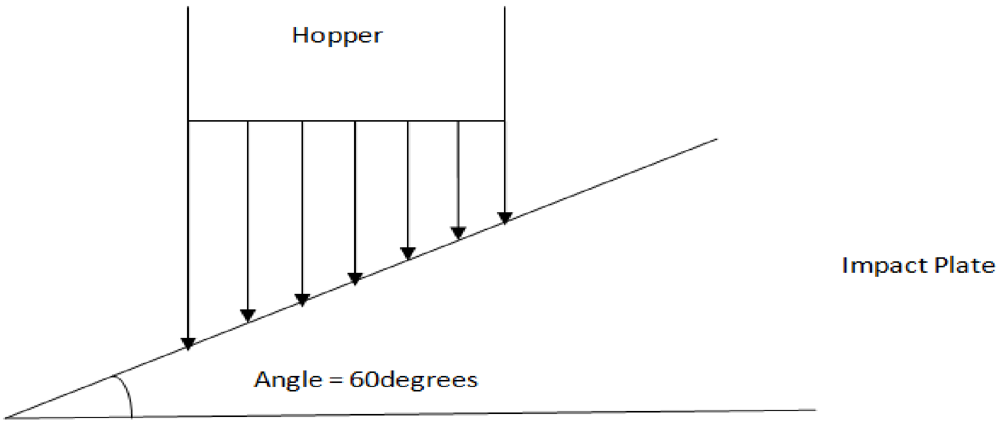

Figure 9: Schematic representation of impact plate flowmeter

Due to height variations along the inclined plate the impact force obtained is variable and hence the mass flow rate. This requires a need of calibration.

Calculations:

- Impact Force calculation:

$F = m.a$ ... (m- mass in kg, a- acceleration)

$F = Q.v$ ... (Q- mass flow rate in kg/sec, v- velocity)

$Q = \rho Av$ ... (ρ- density of dry powder fuel in kg/m^3,A- area in m^2)

Substituting in Force equation:

$$F = (\rho Av)v$$

$$= \rho Av^2$$

From the available data –

- ρ, for dry powder fuel = 0.4gm/cc = $400kg/m^3$
- A , outlet area of hopper = 0.18*0.08 = $0.0144m^2$
- $v = sqrt(2gh)$ ... (g= acceleration due to gravity in m/s^2,

  $= 4.429h^{1/2}$ h= height from which the powder is dropped n the impact plate, in m)

We obtain,

$F = 113.011h$ …(h varies due to inclined plate)

Considering two extreme cases where h is maximum and minimum

For min h, i.e. h = 0.15m

$F1 = 16.95N$

And for max, i.e. h = 0.196m

$F2 = 22.15N$

It is evident that the force varies proportionally with h.

i.e. $F \alpha h$

Because the load cell attached to the impact plate generates values only in horizontal direction, F1’= F1 Cos(60) = 8.475 N

And, F2’ = F2 Cos(60) = 11.075N

- Impact Velocity calculation:

v = sqrt(2gh)

- Mass flow rate calculation:

m = impact force / impact velocity

m1= 4.940 kg/sec

m2 = 5.647 kg/sec

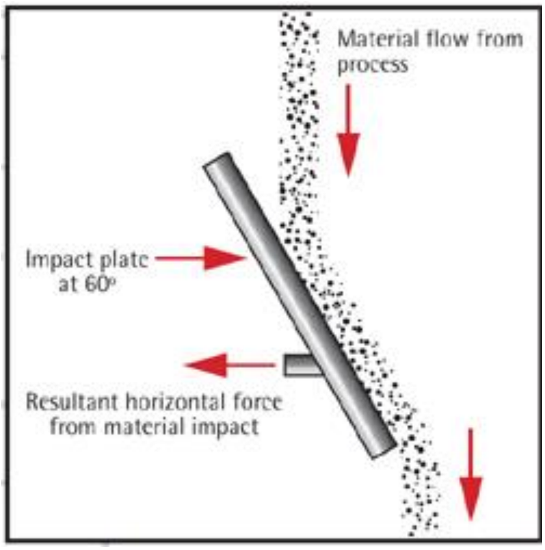

Figure 10: Impact Plate Type Flowmeter

Calibration is done by dropping a known mass of powder from a known height and obtaining the value of the mass to understand the relation between difference in actual value and experimental value and eventually by deriving the relation of this difference with the height of falling mass.

The outcomes after amalgamation of Impact Flowmeter are:

1. Plant Operation: 3 shifts of 8 hrs each
2. Time taken: 75 min/ per batch
3. : 40 boxes/ton of slurry
4. : 360 cartridges
5. 10-12 min saved per shift
6. 30-36 min time reduction per day
7. Additional production of ½ batch per day
8. Increase in output: 20 boxes/day i.e. 180 extra cartridges
9. Reduction in no. of defectives

Problem 2: Unloading of Ammonium Nitrate and carrying it to the storage area is manual and time consuming.

Present Scenario:

- Ammonium Nitrate delivered in trucks of payload capacity 30 tons, 50kg/bag.
- 6 labourers employed for loading-unloading.
- Time taken: 3-4 hrs

Proposed Methodology:

Using a **Telescopic belt conveyor** for unloading of Ammonium Nitrate is a solution for this problem.

Telescopic belt conveyors come into prominence in places in which loading and unloading is made serially, rather than other fixed conveyor systems.

Because of its easy usage and suitable design, by reducing operator need for handling goods manually, it reduces personnel number and provides savings.

Extension and retraction are fully motor-driven, with a fast response to operator actions. The benefits of telescopic belt conveyors include:

- Improved ergonomic working conditions
- Faster loading and unloading
- A safe and reliable operation
- The capacity to transport parcel loads of up to 50 kg/m
- Easy access for maintenance.

Following are the technical specifications of the conveyor to be incorporated:

CONVEYOR SPECIFICATIONS	
Load capacity dynamic	50 kg/m
Static	150 kg/m
Max Belt speed	10-30m/min
Power(kW)	1.1kw,1.5kw,2.2kw
Voltage	380V±10%,3-PH
Boom Speed	10 m/min
Band Material	PVC
Belt Direction	Forward & reverse
Frame	16Mn carbon steel, spray painting
Material Feature	Anti-static & low stretch
Angle	(-2.5°~2)
Efficiency	Finish loading 2250pcs/hour
Cost	Rs. 7,50,000-12,00,000

Table 1: Conveyor Specifications

CONVEYOR DIMENSIONS					
Model	Closed Length(mm)	Open Length	Open length (mm)	Belt width(mm)	Height(mm)
Section	L*1*	vL	L*2*	L*4*	h
3 sections	5400	6600	12000	600	750
3 sections	6000	7500	13500	600	800
3 sections	7000	9600	16600	600	800
4 sections	5400	10000	15400	600	800
4 sections	7000	14000	21000	600	800
5 sections	7600	16000	23600	600	960

Table 2: Conveyor Dimensions

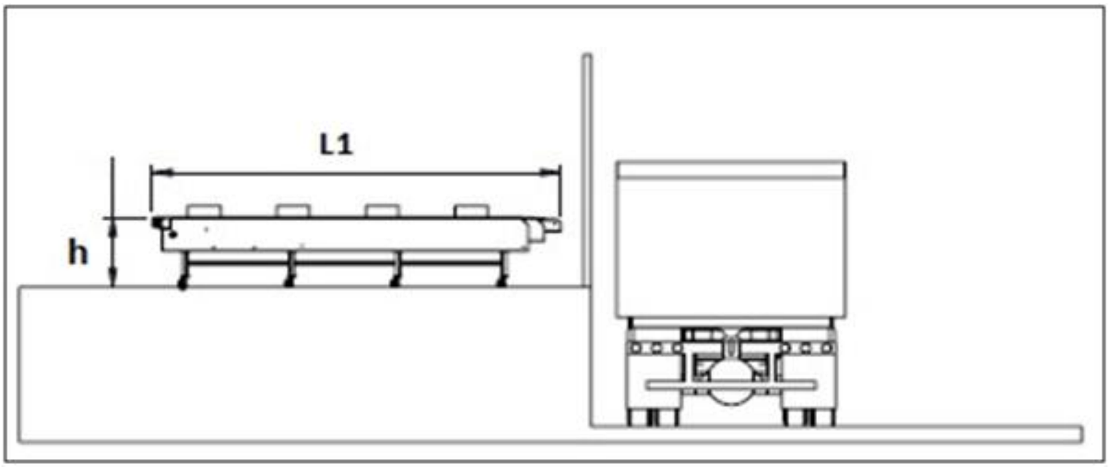

Figure 11: Compact View of Telescopic Conveyor

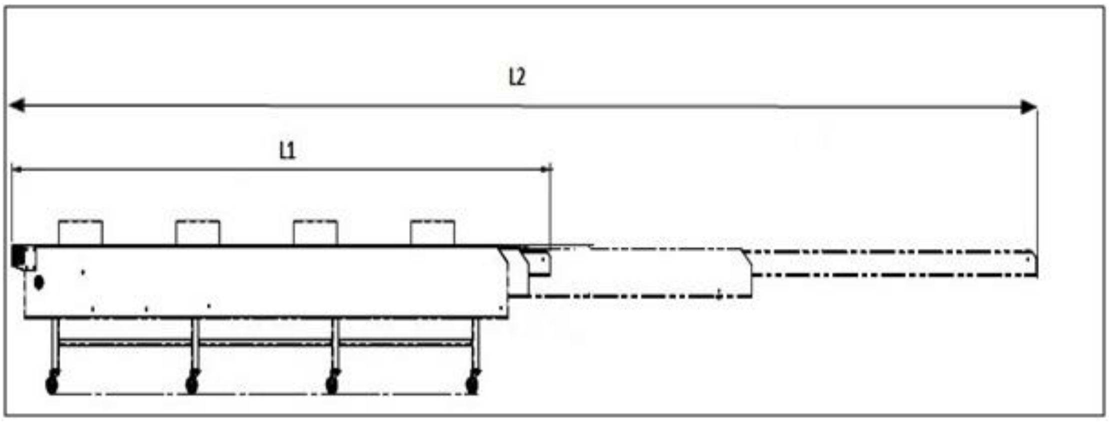

Figure 12: Full View of Telescopic Conveyor

According to the requirements, a 3 section model of closed length 7000mm is appropriate in design and fetches the following results:

Cost Analysis:

1. Labour Wage: Rs 360/day
2. For 6 labourers: Rs. 2160/day
3. Annual Cost for 6 labourers: Rs. 7,88,400
4. Annual Cost For 2 labourers: Rs. 2,62,800
5. Annual Cost Saving: **Rs. 5,25,600**

Time Reduction Analysis:

1. Dynamic Load Capacity: 50 kg/m
2. Belt Speed: 10m/min
3. Unloading rate: 50 x 10 = 500kg/min
4. Total time taken for 30 ton: 30000/500 = 60min i.e. 1 hr
5. Total time reduction: 2-3 hrs

5. **Conclusion**:

The collaborative reverberations of the two problems can be summarised as follows:

- Increased production
- Minimization in number of defectives
- Abatement in cycle time
- Reduction in labor required
- Cost contraction

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