1. **Title of the project**

Utilization of spent weight reduction bath for pollution reduction and energy generation in decentralized textile processing sector (Waste to energy approach)

2. **Principal Investigator(s) and Co-Investigators**

2.1 Principal Investigator

Name	M.G. Parikh
Designation	S.S.O. II

2.2 Co-investigator

1)	**Name**	A.M. Choksi
	Designation	J.S.O. I
2)	**Name**	B.C. Chauhan
	Designation	S.S.A. I

3. **Implementing Institution**

Man Made Textiles Research Association

Near Textile Market Telephone Exchange,
Ring Road, Surat 395 002, Gujarat
Tele. No: 2323211, 2337062
Fax No: 2322500
Gram: `MANTRA'
E-mail: director@mantrasurat.org

4. **Date of commencement** : 01.02.2013

5. **Planned date of completion** : 01.02.2015

6. **Actual date of completion** : 01.02.2015

7. **Objectives as stated in the project proposal:**

1. To study characteristics of weight reduction spent bath for pollution parameters.

2. To develop a simple method of separating byproducts from spent bath and to study it's implementing on shop floor.

3. To study the calorific values of solid waste generated and to assess its impact on air pollution when burnt as fuel

4. To design simple reaction, filtration assembly on shop floor to generate solid waste

5. To cost economic aspect in terms of energy generation and pollution load reduction.

8. Deviation made from original objectives if any, while implementing the project and reasons thereof:

No deviations were made.

9. Experimental work giving full details of experimental set up, methods adopted, data collected supported by necessary table, charts, diagrams & photographs, etc.

9.1.0 Introduction

9.1.1 Surat textile processing cluster

Surat is well known for its synthetic textile products market. It is mainly engaged in the production and trading of synthetic textile products. Nearly 30 million meters of raw fabric and 25 million meters of processed fabric are produced in Surat daily. Around 65% of India's manmade fabric production is done in Surat. The Surat and surrounding area has more than 450 process houses. According to one survey the surat processing industry can be classified into three categories based on production capacity as follows.

i) Small-scale units having production capacity of less than 50,000 meters/day of processing.
ii) Medium size units having production capacity of more than 50,000 meters and below 1,00,000 meters/day.
iii) Large units having production capacity of above 1,00,000 meters/day of processing.

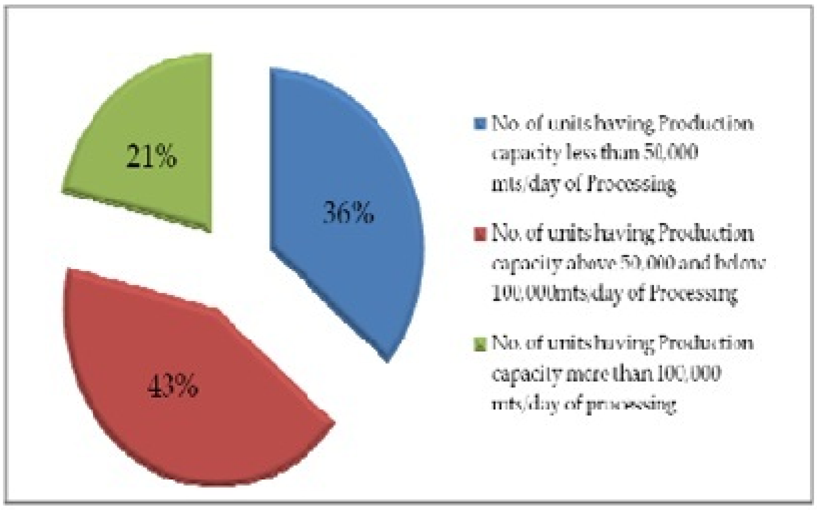
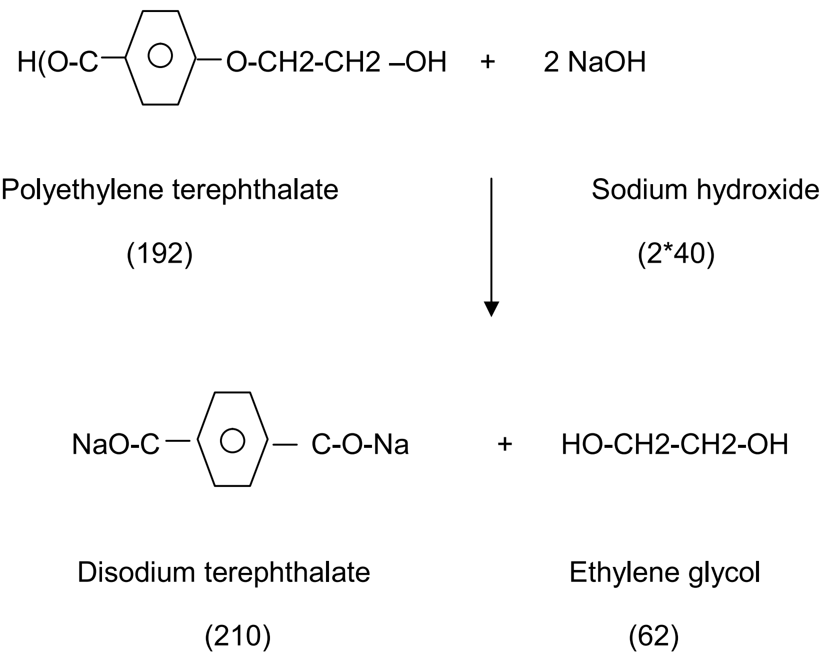


Figure 1 Classification of Units Based on Production Capacity

Out of total production of Surat industry a major portion consist of 100% polyester filament fabrics intended for saree and dress material. These varieties undergo process known as weight reduction which imparts silk like handle and feel to the polyester fabric. The process is leaching of polyester from its surface and it involves use of large amount of caustic soda. Depending upon the variety of fabric weight reduction extent varies from 10% to as high as 30% by weight. The process generates polyester hydrolysis reaction byproducts and it remains with the spent weight reduction bath. These byproducts increase the pollution load of final effluent and contribute to ETP sludge. The ETP sludge is a solid waste generated by a process house and it is dumped in solid waste disposal site. An estimate suggests that about 270 tons of polyester fabric is dissolved and contributes to textile process house pollution every day (considering average of 15% weight reduction & average production of 70000 meters of polyester fabric for 450 process houses).

9.1.2 Theory of weight reduction of polyester

Weight reduction of PET is based on alkaline hydrolysis reaction, which is also known as saponification reaction. When polyester is subjected to hot NaOH solution OH^{-}ion attack carboxyl group in polyethylene terephthalate chain as shown below.



From equation it is clear that for cleavage of 1 mole PET, 2 moles of NaOH are required. From this, theoretical requirement of NaOH for weight reduction can be calculated as follows.

192 kg PET requires 80 gm NaOH

Therefore, NaOH consumption = W x P/100 x 80/192

NaOH consumed = 0.417 x W x P,

Where W = wt. of batch and P = % wt. reduction required.

9.1.2.1 Factors affecting weight reduction of polyester

Following factors affect the rate of weight reduction treatment.

1. Temperature of the treatment.
2. Caustic (NaOH) concentration.
3. Time of the treatment.

4. Presence of accelerant.

It is clear that increase in temperature and concentration of NaOH and time will increase the weight loss. Out of these, temperature is the most sensitive parameter, followed by concentration and then, time. To control the rate of weight reduction, these factors need to be adjusted.

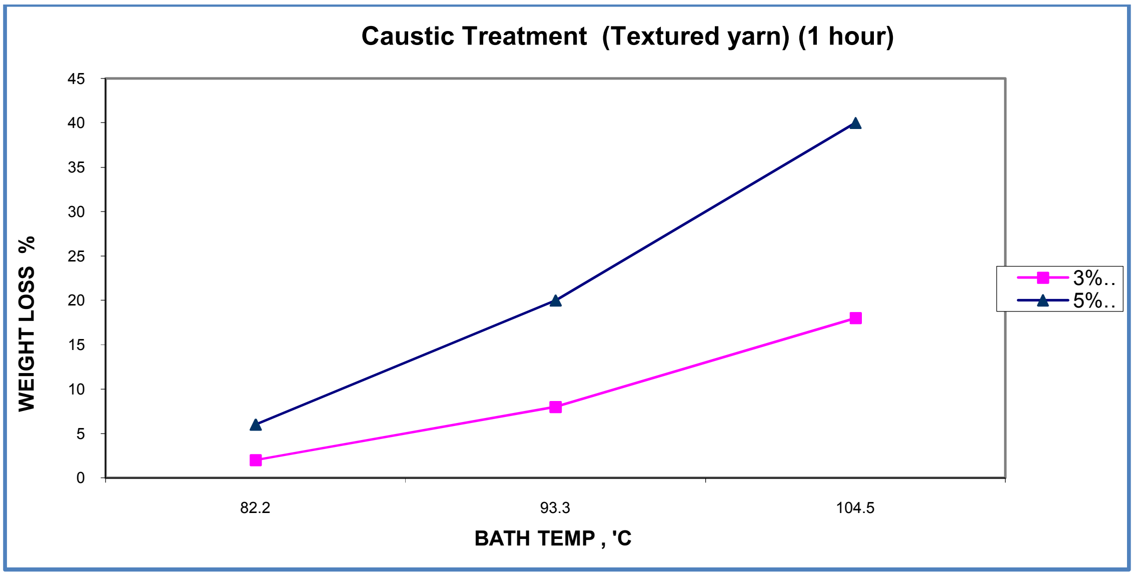


Fig. 2

From the graph (Fig. 2) it is seen that increase in concentration of NaOH from 3 to 5% results in increase in weight loss. In case of increase in temperature from 82 to 93 to 104.5 there is considerable increase in weight loss percentage.

The other factor is use of accelerant. There are some surfactants that work as a catalyst in the process of weight reduction. They do not take part in the reaction but improves rate of reaction drastically. Following graph (Fig. 3) clearly shows the action of addition of an accelerant.

It can be seen from the graph that even after concentration of NaOH is decreased from 5% to 2%, the presence of accelerant causes greater weight loss than what is achieved with 5% NaOH alone. This implies that while using accelerant, greater care is required to control hydrolysis reaction.

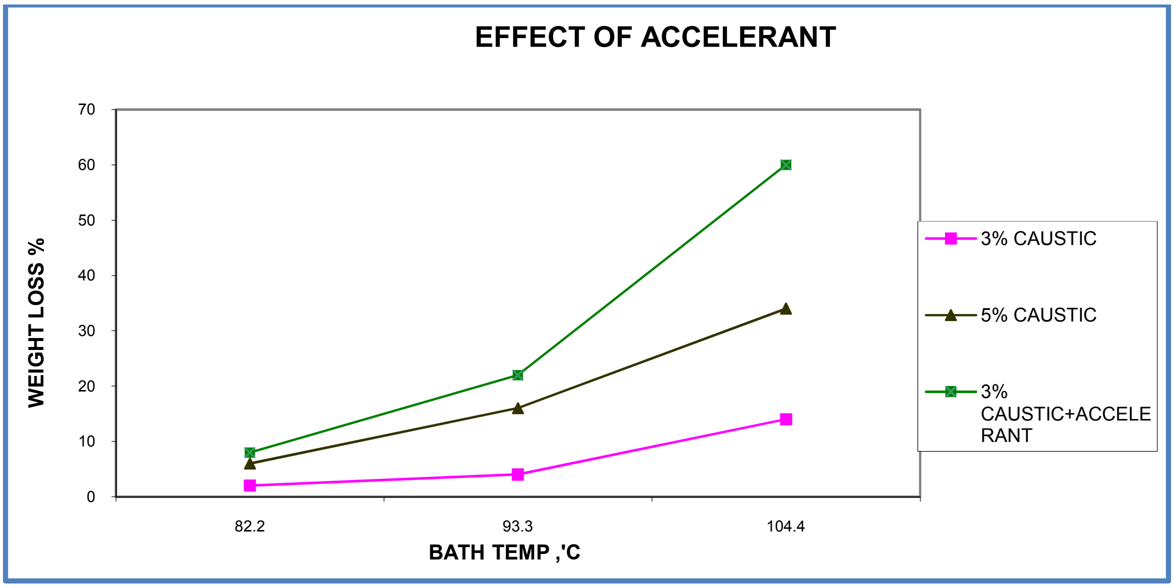


Fig. 3

9.1.2.2 Changes in fabric properties due to weight reduction

Weight reduction is accompanied by reduction in denier of warp and weft yarn in the fabric resulting in reduction in weight per meter of the fabric as well as thickness of the fabric. There is improvement in the feel of the fabric. During weight reduction process, there is reduction in denier, which is always accompanied with decrease in tensile strength of yarn in the fabric. The term "controlled hydrolysis" appearing in the definition of weight reduction bears significance. The extent of weight reduction must be confined to an optimum strength loss. If strength loss exceeds certain limit, then the fabric will become tender. Hence, weight reduction should be controlled in this respect.

In one study it was established that relative fibre strength loss is greater than its corresponding relative weight loss, leading to decline in fibre tenacity. This decline is moderate in flat yarn, but higher in set textured yarn. Use of accelerant causes higher weight loss, e.g. 2.5 times than weight loss generated without using it, but, at the same time, it has detrimental effect on strength degradation. Fig.4 illustrates the correlation of fabric strength loss with fabric weight reduction.

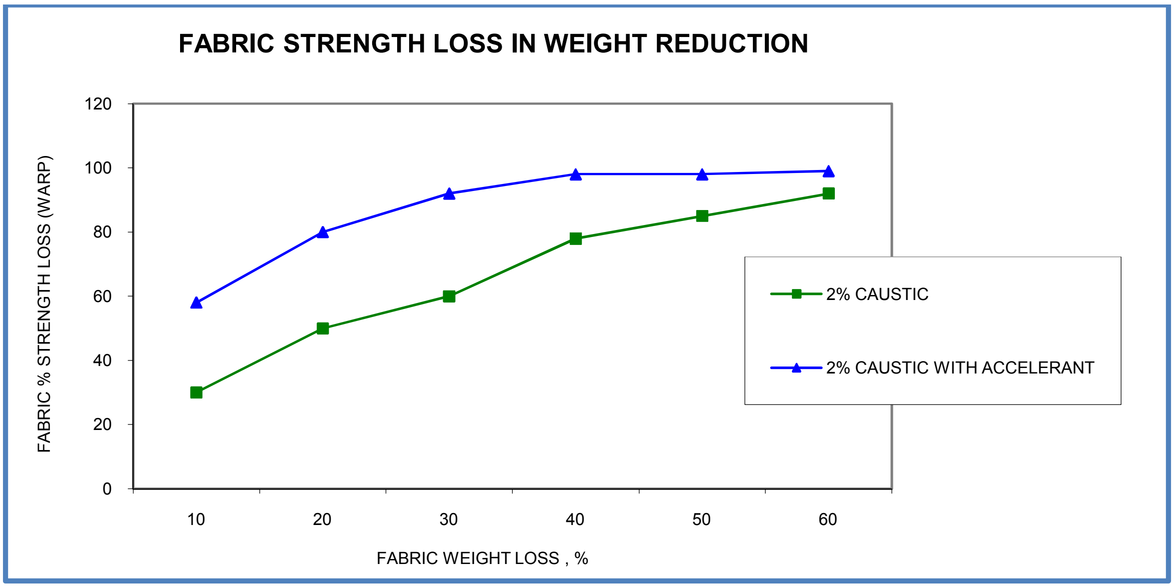


Fig. 4

9.1.3 Industrial process of weight reduction

Process of weight reduction is generally carried out in batch wise fashion in jet dyeing machine. The temperature of treatment, concentration of alkali is decided on %age weight loss required and also whether the fabric is heat set or not. It also depends on whether accerelant is to be added or not. At one time the temperature in jet dyeing was kept in the range of 105 to 125°c but now a day WR treatment is carried out at low temperature around 95°c.

9.1.3.1 Process in fabric weight reduction machine ('Softleena')

This machine was introduced in Surat industry in around 2005. This concept was introduced by Japanese and Korean industries. This is a type of soft flow jet dyeing having four tubes and nozzles. The side and the front layout of the machine is shown in fig. 6 & 7 and the actual image is shown in Fig. 5. It is working at 98°c maximum and is not a high pressure machine. Here weight reduction is carried out at temperature around 95°c with high concentration of alkali and for prolong time. The rate of weight reduction is done in controlled fashion and it is uniform throughout the length and width of the fabric. Generally weight reduction in this machine is done on heat set fabric. The features of the machine are as follows.

DESCRIPTION AND MAIN FEATURES:

- One basket holding capacity 200 kgs of fabric
- Fabric loading capacity 800 kgs (machine with 400 kgs capacity also available)
- Liquor ratio 1:4
- Newly developed high flow nozzle for light and heavy fabric
- The fully folded nozzle and nozzle diameter upto 83mm upto 110mm
- High fabric speed 100-250m /min
- Weight reduction system -30 to 450 grams /mtr. sq. fabric
- Maximum working temperature 98°C
- Heavy duty low RPM pump which consume low power and high discharge of liquor
- Recovery tank capacity 4000 ltr

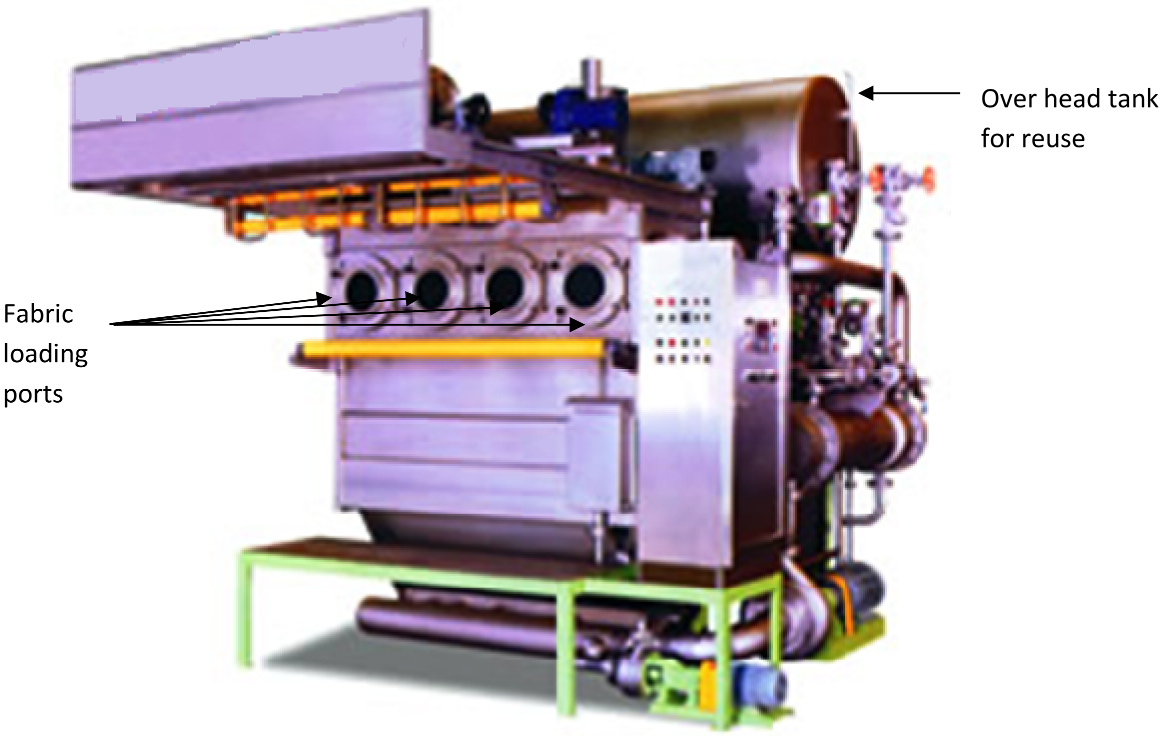


Fig. 5 Softleena

To conserve the excess alkali there is a provision for re use of alkali. At the end of each cycle the residual alkaline solution (spent bath) is lifted to overhead tank with the help of a pump. The residual alkali is measured in the lab and necessary amount of alkali is added for next batch. The residual alkali is re used for several cycles before it is drained. During every cycle the byproducts of weight reduction are added to the residual alkali. So there is accumulation of impurities in the reused spent bath at each stage.

Advantages of fabric weight reduction machine (Softleena):

This machine is like soft flow jet dyeing machine hence the treatment is gentle on fabric without any tension. Further it works at temperature of around 95ºc so there is excellent control over rate of weight reduction. The uniformity of weight reduction is far better than done in jet dyeing machine at higher temperature. The reuse system allows saving in terms of caustic and water consumption. The spent bath lifted when reused for the next batch is hot (about 70ºc) so there is also some amount of energy saving. However the machine suffers some limitations as narrated below.

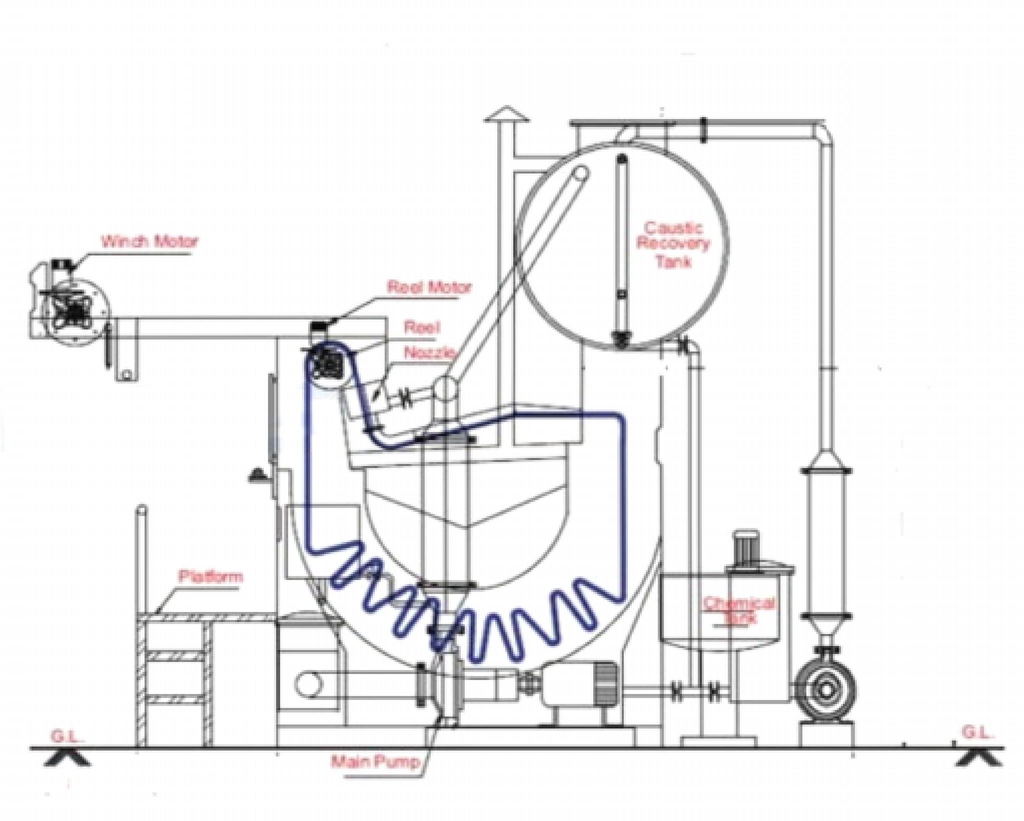


Fig. 6 Fabric weight reduction machine (side view)

Disadvantages of fabric weight reduction machine (softleena)

The machine has following limitations.

At each reuse cycle there is an increase in amount of impurities. Many times the valves and pump gets clogged and there is maintenance break due to this. The impurities accumulated also deposits on the fabric and not easily washed away. This causes problems in subsequent printing. The fabric is not perfectly adhered to the blanket of the machine. The treatment in this machine is given at 95ºc and hence requires long process time with high concentration of alkali. The production is relatively less than process carried out in a jet under high temperature and pressure.

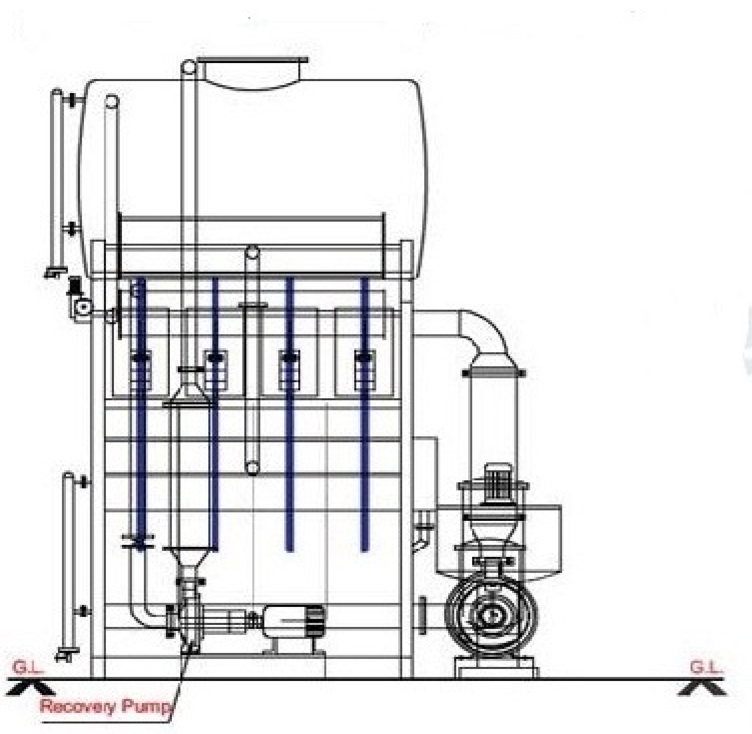


Fig. 7 Fabric weight reduction machine (Front view)

9.1.3.2 Continuous process of weight reduction

The process of weight reduction can also be done in continuous way. The polyester fabric is padded with NaOH solution and steamed at 102°c for certain dwell time and subsequently washed and neutralized. This is more accurate method of polyester fabric weight reduction as the process is done in open width form. There is uniform weight reduction along the length and width of the fabric. Further the process is much faster than batch wise process of weight reduction. A schematic diagram of continuous weight reduction range is shown in following figure 8.

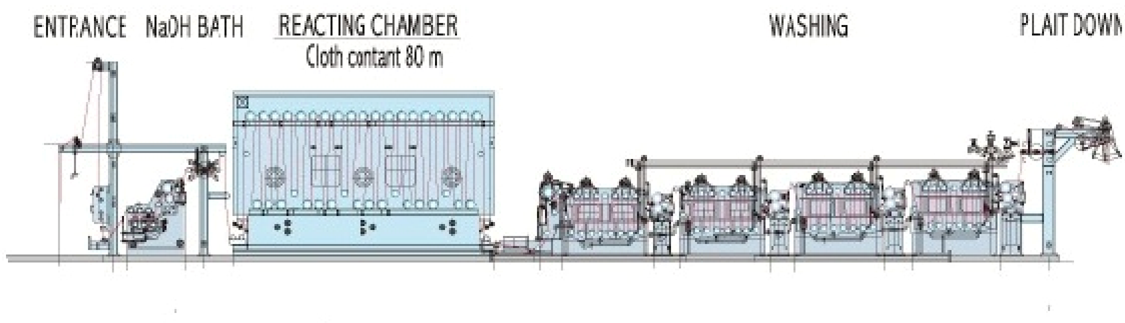


Fig. 8 Continuous weight reduction range (CWR)

Advantages of Continuous WR

The process is carried out in open width by pad steam method. The process is very fast and hence production is high. Unlike Softleena there is no problem of impurities build up. There is better uniformity of treatment and piece to piece variation is not found.

Limitations of CWR

The CWR is suitable where long length of fabric is given weight reduction for one percentage. Generally percentage weight reduction varies with different fabric varieties and final feel required. It is not easy to change concentration of caustic or speed of the fabric frequently. Therefore many times a fixed weight reduction is given and then correction or additional weight reduction is achieved in subsequent scouring in jet dyeing machine.

9.1.4 Byproducts of weight reduction

When polyester fabric undergoes process of weight reduction due to alkaline hydrolysis of polymer following byproducts are produced,

1. Sodium salt of Terephthalic acid
2. Ethylene glycol
3. Oligomers

9.1.4.1 Terephthalic acid

Terephthalic acid is organic compound with molecular formula $C_8H_6O_4$ (See fig. 9). It is used principally as a precursor to the polyester PET used to make fiber and plastic bottles. It exhibits following properties.

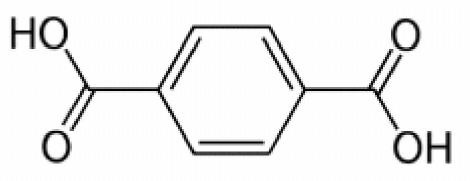


Fig. 9 Molecular Structure Terephthalic acid

Molecular formula	$C_8H_6O_4$
Molecular weight	166.13
Density	1.522
Melting point	300ºc
Boiling point	Sublimes (at 400ºc)
Solubility in water	0.0017 g/100ml at 25ºc

Material safety data sheet of Terephthalic acid

The summary of terephthalic acid MSDS is as follows.

Chemical Name: Terephthalic Acid

Chemical Formula: C8-H6-O4

Synonym: 1,4-Benzenedicarboxylic Acid

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: 495°C (923°F)

Flash Points:OPEN CUP: 260°C (500°F).

Flammable Limits: Not available.

Products of Combustion:	These products are carbon oxides (CO, CO2)
Products of Biodegradation:	Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation:	The product itself and its products of degradation are not toxic

9.1.4.2 Ethylene Glycol

Ethylene glycol is another monomer liberated during hydrolysis of polyester (See fig. 10). Its formula is $C_2H_6O_2$.

Fig 10. Structural formula Ethylene Glycol

Properties	
Molecular formula	$C_2H_6O_2$
Molar mass	62.07 g·mol^{-1}
Appearance	clear, colorless liquid
Odor	odorless
Density	1.1132 g/cm^3
Melting point	−12.9 °C

Boiling point	197.3 °C
Solubility in water	Miscible
Solubility	soluble in most organic solvents
Vapor pressure	0.06 mmHg (20°C)[1]
Viscosity	1.61×10^{-2} N*s / m2[

Since Ethylene glycol is fairly miscible in water it is carried away with the washing liquor and contributes to water pollution.

9.1.4.3 Oligomers

Typically polyester fibers contain between 1.5 and 3.5% by mass of low Molecular esters, the principal oligomer being cyclic tris (ethylene terephthalate) (see fig 11) with smaller quantities of a dimer, pentamer as well as traces of other compounds.

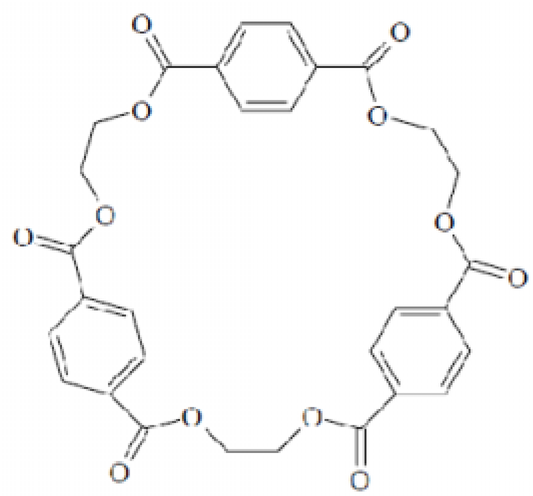
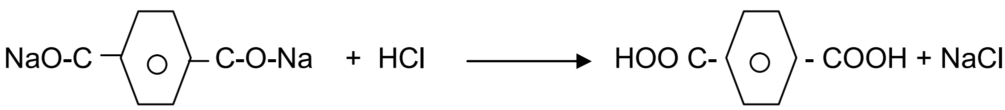


Fig. 11 Cyclic trimer of polyester

These oligomers tend to come out from the structure of fiber during processing at high temperature of dyeing. During process of weight reduction with removal of monomers from the surface of fiber the oligomers are also removed easily. Since in softleena machine the several reuse cycles are followed and hence at each stage there would be accumulation of oligomers to some extent in the spent weight reduction bath along with terephthalic acid.

9.1.5 Principal of isolation of Terephthalic acid as solid waste

In weight reduction spent bath the Terephthalic acid liberated during process remains as its sodium salt which is soluble in water. To isolate it as solid it has to be converted into its original insoluble form. This can be done by reacting it with strong inorganic acid like Hydrochloric acid.



Thus simply by reacting disodium terephthalate with HCl we get precipitate of Terephthalic acid. This along with some oligomers and other impurities can be isolated as solid waste. This will not only reduce pollution load in final effluent but can be utilized as fuel by mixing it with coal or lignite.

9.1.6 Principal of automation

To make the process automatic controlled addition of reagents and drainage of unwanted byproduct has to be achieved in a continuous fashion. This can be done by using pneumatic control (on/off) valve and linking with electronic controller through solenoid valve. Further measurement of pH has to be sensed and acid addition has to be controlled as per pH sensor.

9.1.6.1 pH measurement and pH sensor

The pH of a solution indicates how acidic or basic (alkaline) it is. The pH term translates the values of the hydrogen ion concentration which ordinarily ranges between about 1 and 10 x -14 gram-equivalents per litre - into numbers between 0 and 14.

On the pH scale a very acidic solution has a low pH value such as 0, 1, or 2 (which corresponds to a large concentration of hydrogen ions; $10x^{0}$, $10 x^{-1}$, or $10 x^{-2}$ gram-equivalents per litre) while a very basic solution has a high pH value, such as 12, 13, or 14 which corresponds to a small number of hydrogen ions ($10 \times^{-12}$, $10 \times^{-13}$, or $10x^{-14}$ gram-equivalents per litre). A neutral solution such as water has a pH of approximately 7.

A pH measurement loop is made up of three components, the pH sensor, which includes a measuring electrode, a reference electrode, and a temperature sensor; a preamplifier; and an analyser or transmitter. A pH measurement loop is essentially a battery where the positive terminal is the measuring electrode and the negative terminal is the reference electrode. The measuring electrode, which is sensitive to the hydrogen ion, develops a potential (voltage) directly related to the hydrogen ion concentration of the solution. The reference electrode provides a stable potential against which the measuring electrode can be compared.

9.1.6.2 Control valve

Control valves are valves used to control conditions such s flow, pressure, temperature, and liquid level by fully or partially opening or closing in response to signals received from controllers that compare a "set point" to a "process variable" whose value is provided by sensors that monitor changes in such conditions. The opening or closing of control valves is usually done automatically by electrical, hydraulic or pneumatic actuators. Positioners are used to control the opening or closing of the actuator based on electric, or pneumatic signals. A control valve consists of three main parts in which each part exist in several types and designs:

- Valve's actuator
- Valve's positioner
- Valve's body

A **solenoid valve** is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

9.1.7 Reference

1. Gorrafa A.A.M., TCC, 12, 1980, 50
2. Houser K.D. TCC, 15, 1983, 70
3. Chemical processing of synthetic fibers and blends; K.V. Datye, A.A. vaidya; John Wiley & sons,1994, p. 457
4. Weight reduction of polyester, M.G. Parikh, MANTRA Bulletin, Nov 2004, 9
5. Shenai V.A., Nayak N.K., Textile Dyer and Printer, No.11, 1981.
6. Namboori and Heith, J. Appl. Poly. Sci., 12 (1968), 9, 1999.
7. Processing energy from waste, E. Milton Wilson, Harry M. Freeman, 430, Environmental Science and Technology
8. Efficient waste processing and waste to energy: Challenge for the future, Petr stehlik, guest column published online, Springer-Verlag 2008
9. Research on Development of Processing and Disposal of Sludge, DANG Zheng-guang (Liaohe Petroleum Refinery of China National Petroleum Corporation,Panjin124022, China)
10. Recent advances in the development of silk like polyester fabrics, Pushpa Bajaj, Indian journal of fiber & textile research, vol 21, march 1996, pp 79-89.
11. Weight reduction of microfibre polyester fabric and the effect on its physical and mechanical properties, F. Mousazadegan[a], S. Saharkhiz[a*] & M. Maroufi[a] , Journal of the Textile Institute Volume 101, Issue 8, 2010, pages 716-728

9.2 working methodology

1. The weight reduction spent bath samples were collected from different process houses and analyzed in the laboratory for various parameters

2. The weight reduction spent bath samples were collected from one process house but at the end of each reuse cycle and properties at each stage was evaluated.

3. Weight reduction spent bath was treated in the laboratory using floculater and solid waste was generated in the laboratory. The solid waste was analyzed for GCV and other properties

4. A small manual plant was designed and constructed to generate solid waste from spent bath on the shop floor. The plant was made operational in three process houses. Solid waste was generated.

5. The solid waste generated from weight reduction spent bath was mixed with coal in different proportion and charged in boiler and simultaneous stack monitoring was done to check air pollution parameter.

6. A plant with automatic pH dosing and control was designed and installed in a local process house. The working of plant was checked for efficiency.

7. Cost economic aspects are considered.

9.3 Materials and methods

9.3.1 Weight reduction spent bath

This was collected from local process houses.

9.3.2 Chemicals

Laboratory grade chemicals were used for laboratory trials. Whereas for shop floor trials commercial grade chemicals were obtained from local bulk chemical suppliers.

9.3.3 Testing equipments

- Strength tester Lloyd (U.K.)
- Twist tester (digital)

- Digital bomb calorimeter
- Stack monitoring kit
- COD digester
- BOD incubator
- UV visible spectrophotometer
- Differential Scanning Calorimeter (DSC, Mettler)

9.3.4 Floculater

Laboratory Floculater from Santrofix, Mumbai with six beakers was used for generating solid residue in the laboratory (see fig. 12)

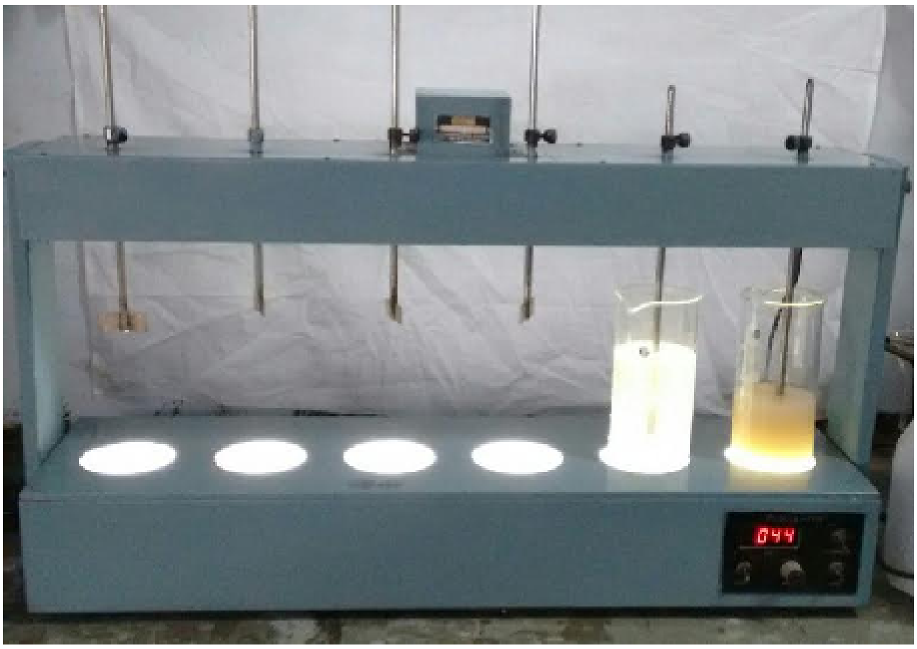


Fig.12: Floculating machine

9.3.5 Laboratory equipment used

For laboratory study weight reduction trials were conducted in IR beaker dyeing machines. For pad dry steam trials laboratory padding mangle and multipurpose programmable steamer (both from R.B. Electronics) were used.

9.3.6 Softleena machine

Fabric weight reduction machine were selected from different process houses selected in different industry cluster. The machines were selected according to two different sizes.

9.3.7 Continuous weight reduction range

Continuous weight reduction range was selected from one process house situated in GIDC pandesara, Surat

9.4 Testing standard methods

Test methods followed during the course of the study are shown in table 1.

Table 1 Test & methods

Sr. No.	Material	Test name	Test number
1	Spent bath	Turbidity	IS 3025 (Part 10) : 1984
2		Temperature	IS : 3025 (Part 9) - 1984
3		Specific conductance	IS 3025 (Part 14) : 2013
4		Total dissolved solids	IS 3025 (Part 16) : 1984
5		pH value	IS 3025 (Part II) : 1983
6		Total suspended solids	IS : 3025 (Part 17) - 1984
7		Iron	IS 3025 (Part 53) : 2003
8		Total hardness	IS 3025 (Part 21) : 2009
9		Total alkalinity	IS 3025 (PART 23): 1986
10		Sulphates	IS : 3025(Part 24)-1986(Reaffirmed 1992
11		Chemical Oxygen Demand (COD)	IS 3025 (part 58)

12		Bio chemical oxygen demand (BOD_3)	IS 3025 (part 44)
13	Solid residue	Gross Calorific Value (GCV)	IS 1350 Part II
14	,,	Ash Content	IS 1350 Part I
15	,,	Melting point	
16	Boiler flue gas	Suspended particulate matter (SPM)	IS 11255 part 3 2008
17	Boiler flue gas	Oxides of Sulphur (SOX)	IS 11255 part 2 1985
18	Boiler flue gas	Oxides of Nitrogen (NOX)	IS 11255 part 7 2005

9.5 Characterization of weight reduction spent bath

9.5.1 Collection of spent bath samples at different stages of reuse

According to industrial practice weight reduction bath is reused for several cycles. Hence weight reduction spent bath samples were collected from one process house from each batch starting from initial to 20th reuse cycle. These samples were analyzed in the laboratory for properties like TDS & COD to assess pollution load on ETP. The analysis is shown in table no 2.

Table 2 pollution level at each reuse cycle

Sr. No.	Reuse no.	Caustic Addition	COD	TDS mg/lt
1	Initial NaoH Sol.	42 Kg Flaks	8,393	48506
2.	Batch No 1	Initial	31,418	21988
3	Batch No 2		52,398	119460
4	Batch No 3	51 Kg	78,318	133650
5	Batch No 4	50 Kg	1,56,925	126640
6	Batch No 5	32 Kg	2,82,768	169780
7	Batch No 6	44 Kg	2,62,080	139040
8	Batch No 7	30 Kg	2,75,940	196090
9	Batch No 8	52 Kg	2,95,560	128000

10	Batch No 9	43 Kg	2,47,060	185475
11	Batch No 10	29 Kg	3,51,960	157250
12	Batch No 11	54 Kg	1,85,470	144750
13	Batch No 12	27 Kg	3,80,920	145680
14	Batch No 13	48 Kg	2,82,800	167710
15	Batch No 14	50 Kg	2,73,982	141130
16	Batch No 15	44 Kg	2,18,220	154510
17	Batch No 16	34 Kg	2,30,360	156680
18	Batch No 17	50 Kg	2,51,710	153760
19	Batch No 18	41 Kg	2,79,840	147560
20	Batch No 19	29 Kg	2,21,290	150464
21	Batch No 20	45 Kg	2,03.450	141994

The samples were also tested for total alkalinity to assess residual alkali. Further the samples were neutralized with HCl to precipitate solid residue. The results are given in table no 3.

Table 3 precipitate at each cycle

Sr. No.	Reuse no.	Caustic Addition	Total Alkalinity Kg/Batch	PPT gm/lit
1	Initial NaoH Sol.	42 Kg Flaks	0.869	2.21
2.	Batch No 1	Initial	0.395	3.327
3	Batch No 2		1.8	25.95
4	Batch No 3	51 Kg	1.9	41.26
5	Batch No 4	50 Kg	1.34	47.69
6	Batch No 5	32 Kg	1.81	33.50
7	Batch No 6	44 Kg	1.34	37.36
8	Batch No 7	30 Kg	1.89	69.91
9	Batch No 8	52 Kg	1.8	103.03
10	Batch No 9	43 Kg	0.992	120.9
11	Batch No 10	29 Kg	1.424	127.2

12	Batch No 11	54 Kg	1.488	94.6
13	Batch No 12	27 Kg	1.2	106.5
14	Batch No 13	48 Kg	1.3	93.6
15	Batch No 14	50 Kg	1.008	90.3
16	Batch No 15	44 Kg	1.424	130
17	Batch No 16	34 Kg	1.008	121.6
18	Batch No 17	50 Kg	1.18	132.8
19	Batch No 18	41 Kg	1.76	109.2
20	Batch No 19	29 Kg	0.864	89

9.5.2 Characterization of W.R. spent bath

a) The weight reduction spent bath was collected from about 10 process houses located in three different processing clusters. At all these process houses the process of weight reduction was done by exhaust method in soft flow weight reduction machine. The samples were analyzed for 16 parameters. The results are shown in following table number 4,5 & 6.

I Name of the area: G.I.D.C Pandesara

Table 4

Sr No	parameter	Results			
		P 1	**P 2**	**P 3**	**P 4**
1	Turbidity	1020	980	1030	990
2	Appearance	Slightly yellow	Milky white	Water white	Slightly yellow
3	Temperature	70ºc	75ºc	72ºc	74ºc
4	Silica	Nill	Nill	Nill	Nill
5	Total Dissolve solid	139040 mg/lt	120506 mg/lt	148002 mg/lt	117567 mg/lt
6	pH value	13.26	13.0	12.98	13.02
7	Total suspended solid	1444	1326	760	990
8	Iron	Nill	Nill	Nill	Nill
9	Total Hardness	4919	4874	4320	3900

	(as caco3)				
10	Chloride (as cl)	5544	5312	5124	4924
11	Total Alkalinity (as caco3)	57948	56420	54560	55200
12	Carbonates (as co3)	4920	4624	4456	4018
13	Hydroxide (as OH)	38.3	36.9	34.8	33.2
14	C.O.D	427000	320024	478206	321620

II Name of the area: G.I.D.C Sachin

Table 5

Sr No	parameter	Results		
		S 1	**S 2**	**S 3**
1	Turbidity	852	928	963
2	Appearance	Milky Slightly	yellow white	Milky
3	Temperature	75ºc	82ºc	78ºc
4	Silica	Nill	Nill	Nill
5	Total Dissolve solid	128920 mg/lt	94250 mg/lt	131250 mg/lt
6	pH value	13.00	13.20	13.02
7	Total suspended solid	988	1021	560
8	Iron	Nill	Nill	Nill
9	Total Hardness (as caco3)	989	1820	2210
10	Chloride (as cl)	4472	3962	3201
11	Total Alkalinity (as caco3)	49200	50250	49962
12	Carbonates (as co3)	3862	2852	3425
13	Hydroxide (as OH)	28.6	29.6	30.6
14	C.O.D	324600	278250	335236

III Name of the area: Textile Eco park, Palsana

Table 6

Sr No	**parameter**	**Results**	
		E 1	**E 2**
1	Turbidity	980	1020
2	Appearance	Yellowish	Water white
3	Temperature	78ºc	74ºc
4	Silica	Nill	Nill
5	Total Dissolve solid	128300 mg/lt	118324 mg/lt
6	pH value	13.16	13.20
7	Total suspended solid	1264	1180
8	Iron	Nill	Nill
9	Total Hardness (as caco3)	3962	3220
10	Chloride (as cl)	4652	3982
11	Total Alkalinity (as caco3)	46230	39862
12	Carbonates (as co3)	3982	4260
13	Hydroxide (as OH)	32.02	35.3
14	C.O.D	382200	282024

b) Similarly weight reduction spent bath was collected from a process house who is doing weight reduction process in continuous weight reduction range. This facility is available with few process houses and hence only one sample was collected and analyzed. The results for 16 parameters are shown in following table 7.

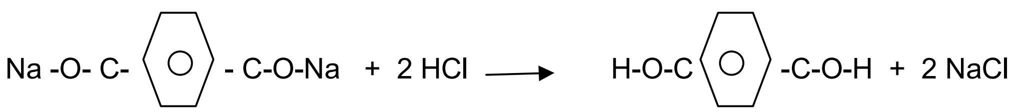
Table 7 (P CWR)

Sr No	**parameter**	**Results**
1	Turbidity	1140
2	Appearance	Slightly yellowish
3	Temperature	75°c

4	Silica	Nil
5	Conductivity	80564
6	Total Dissolve solid	1,36,644 mg/lit
7	pH value	12.97
8	Total suspended solid	658 mg/lit
9	Iron	7.4 mg/lit
10	Total Hardness (as caco3)	5190 mg/lit
11	Chloride (as cl)	66,400 mg/lit
12	Total Alkalinity (as caco3)	13,500 mg/lit
13	Carbonates (as co3)	4850 mg/lit
14	Hydroxide (as OH)	7762 mg/lit
15	Sulphates (as So4)	1588 mg/lit
16	C.O.D	81320 mg/lit

9.6.0 Solid waste generation procedure:

The spent bath of weight reduction process consists of byproducts of alkaline hydrolysis of polyester. Thus it consists of terephthalic acid and ethylene glycol. The terephthalic acid is in the form of its sodium salt and therefore soluble in spent bath. The ethylene glycol is fairly miscible in water. The solid waste can be easily generated by neutralizing spent bath with Hydrochloric acid so that the sodium salt of terephthalic acid is converted into terephthalic acid which is insoluble in water and hence precipitated as solid residue. The ethylene glycol being water miscible and is washed away. Thus terephthalic acid is the only major constituent of the solid waste generated.



Di sodium Phthalate Acid Terephthalic acid Salt

(Soluble) (insoluble)

Polyester fiber contains oligomers within its structures. These are cyclic trimers or tetramers. These oligomers are also leached out and it may be present in the solid waste generated by process of weight reduction.

9.6.1 Solid waste generated in the laboratory

The weight reduction spent bath collected from industry was taken in a beaker in the laboratory. The beaker containing 500 ml of spent bath was placed on floculater as shown in figure 6. The stirrer was started and 10% HCl was added drop wise to generate residue. The acid addition was stopped on reaching pH = 7. The solution was allowed to settle, filtered and residue was washed and dried. The residue was evaluated for properties as shown below.

9.6.2 Solid waste characterization

Weight reduction bath collected from 5 different process houses were given treatment as above and solid residue generated was subjected to analysis for important properties like Gross calorific value and ash. The results are summarized in following table 8.

Table 8

Sr No	parameter	Results					
		Unit I	Unit II	Unit III	Unit IV	Average	Unit V CWR
1	Gross Calorific Value	3965	3577	4424	4726	4178	5252
2	Ash content	14.7	13.9	15.7	14.9	14.8	5.7
3	Moisture content	0.85	0.92	0.89	0.95	0.90	0.88

Further the soli residue was analyzed on DSC. The DSC profile obtained is shown in fig 13.

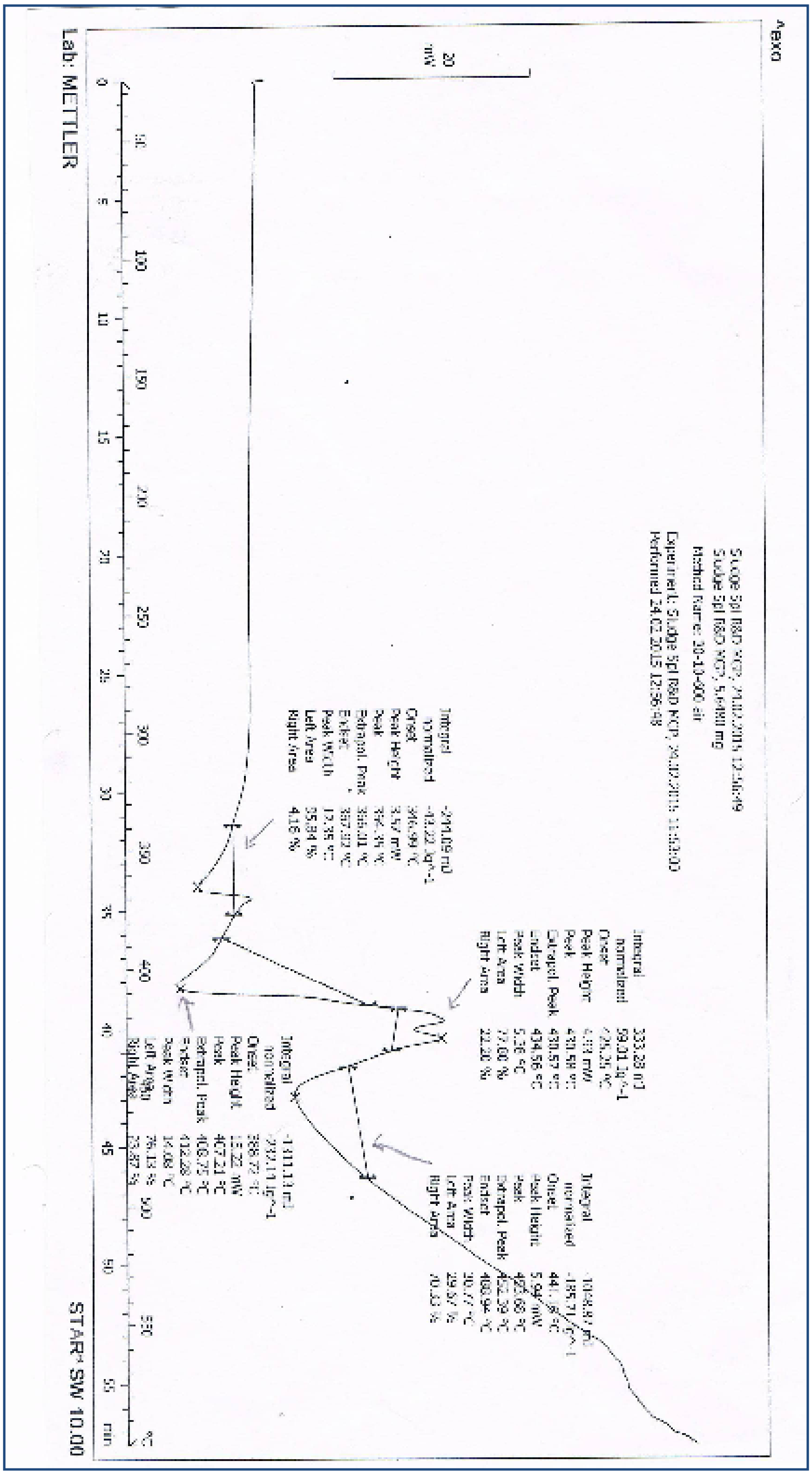


Fig. 13 DSC profile of solid waste

9.6.3 Pilot scale plant to generate solid waste (Manual)

A simple arrangement as shown in figure 14 was made to generate solid waste from eight reduction spent bath. As shown in the figure a 200 liter HDPE plastic tank (Sintex brand) was placed on a stand near weight reduction machine. Two holes were drilled, one at the bottom and the other at the side wall. The pvc water pipe was fixed on each hole and provided with manual valve. The hole on side wall was provided to drain clear water out of the tank once the solid waste generated was settled at the bottom. The bottom hole and the pipe were provided to take out solid waste generated once a sufficient quantity is accumulated at the bottom of the tank. From drain outlet pipe of the machine a flexible plastic pipe was extended which can enter the alkaline spent bath when ever required. A valve was also provided in this pipe.

Working of the plant:

Initially spent water bath was collected in tank by opening the valve 1 of spent WR water in pipe coming from overhead tank of the machine. Once the upper level was reached the addition was stopped. With the help of a plastic pot a commercial grade hydrochloric acid (32% HCl) was gradually added from top of the tank as shown in the diagram. The solution was periodically stirred with a wooden stick. The pH of the solution was checked intermittently and acid addition was continued till pH of the solution reached 7. After that the solution becomes turbid because of the solid waste in the form of precipitate generated. It was allowed to stand for some time till all precipitate gets settled at the bottom. The valve 2 of the side wall pipe situated in the centre was then opened to drain the supernatant solution.

The valve at the top was again opened to take fresh spent water bath to fill the tank to upper level. Acid was again added to precipitate the residue. The procedure was repeated for several cycles till sufficient amount of the solid waste is collected. Then after taking the clear solution out the valve at the bottom was opened and solid waste was taken out in a suitable container. The solid waste collected was in the form of thick slurry and the water was allowed to evaporate and solid was dried by keeping it on open bed.

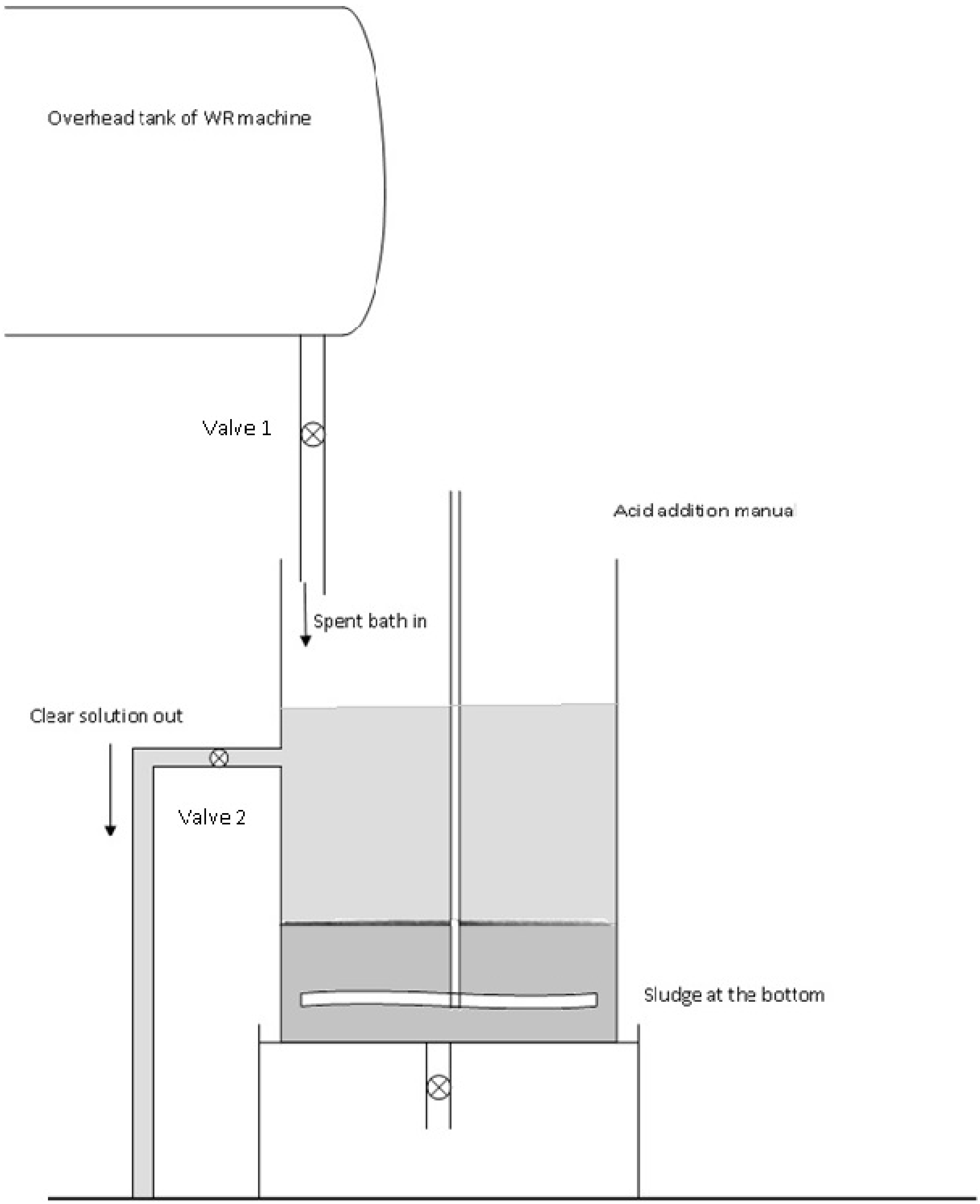


Fig. 14 Schematic diagram of plant (Manual)

This type of manual plant was installed in five different process houses located at different clusters of Surat textile processing industry. We have extracted about 500 kg of solid waste which was utilized for charging boiler after mixing it with coal/lignite.

The solid waste samples were collected and taken to the laboratory of MANTRA for analysis of GCV, ash content, etc the results are summarized in following table.

Table 9 Testing of solid waste generated

Sr No	**parameter**		**Results**				
		P 1	**P 2**	**S 1**	**S 2**	**Average**	**P CWR**
1	Moisture content	0.09	0.092	0.0894	0.091	0.0906	0.092
2	Gross Calorific Value	4300	4620	3994	4150	4266	5200
3	Ash content	13.1	16.4	17.6	12.8	14.97	5.6
4	Volatile matter	76.41	72.2	71.51	76.21	74.06	75.91
5	Fixed carbon	10.4	11.3	10.8	10.9	10.87	18.4

To study the cost economic aspects in manual plants located at different places a study of amount of HCl (28%) required to generate solid residue was conducted. At the same time the solid residue at each instant was separated, dried and weighed. The results are as shown in following table 10.

Table 10 Consumption of acid and solid waste quantity generated

Code of the unit	Amount of HCl (28%) required to neutralize 100 liter of spent bath	Average HCl (28%) required per 100 lit of spent bath	Solid residue generated in Kg	Average waste generated per 100 lit of spent bath
P 1	8.2	8.1	3.93	4.08
P 2	8.4		4.17	
S 1	7.8		4.3	
S 2	8.0		3.92	
P CWR	1.8	N.A.	0.92	N.A.

9.6.4 Automation of the manual plant

The automation in the above simple manually operated plant was necessary to make it more users friendly that will also eliminate need for complicated training for workers. The most important part was to sense the pH of the solution as acid addition goes on. The pH of any solution can be measured accurately by using pH sensor. An online pH control system with progressive dosing facility was developed as per our requirement through a reputed electronic system manufacturing unit. The plant essentially consists of a pH sensor, pneumatic valves, solenoid valve, a stirrer, and programmable acid dosing and pH monitoring unit. The schematic diagram of the plant is given in fig.15. The online programmable pH monitor & control system with programmable dosing facility was designed as per our requirement and supplied by M/s Semitronik Ltd., Ahmedabad. The construction of the plant is as below.

Construction:

A 225 lit. capacity tank of HDPE was placed on a stand near soft flow fabric weight reduction machine. From the overhead tank of the machine a pipe was extended in to the main tank of solid waste generating unit. It was provided with pneumatic control valve 1 as described in section 9.1.6.2 (also see fig. 15 & 19). This valve was timer based and was connected to the control panel of the programmer unit via solenoid valve S1 which was placed in the air pipe of the pneumatic valve 1.

A small over head tank of acid resistance plastic of 50 lit capacity was placed at a height near the main tank on a stand to store the acid. A separate stand was prepared for the purpose. To fill the acid overhead tank at height a buffer tank was provided at the ground level from which acid could be lifted as per requirement by acid resistant pump. The acid inlet was provided by extending a pipe from overhead acid tank into the main tank where in between a pneumatic control valve 2 was provided (see fig. 15 & 17). The control valve 2 was connected to programmer unit via solenoid valve S2 which was placed in the air pipe of valve 2 and it was operated as per pH controller to achieve set pH.

At the mid way a clear solution outlet was also provided with pneumatic valve 3 (see fig. 15 & 18) as shown in the figure. This valve again was timer based and connected to control panel of the programmer via solenoid valve S3.

To stir the solution during acid addition a stirrer was necessary. A low speed stirrer (0.25 HP motor) with variable frequency drive was designed by us and made by a local manufacturer. The stirrer was having length of the probe long enough so that it reaches slightly above (about 2 inches) from bottom of the tank. The impeller of the stirrer was straight and long enough so that it covers the entire width of the tank.

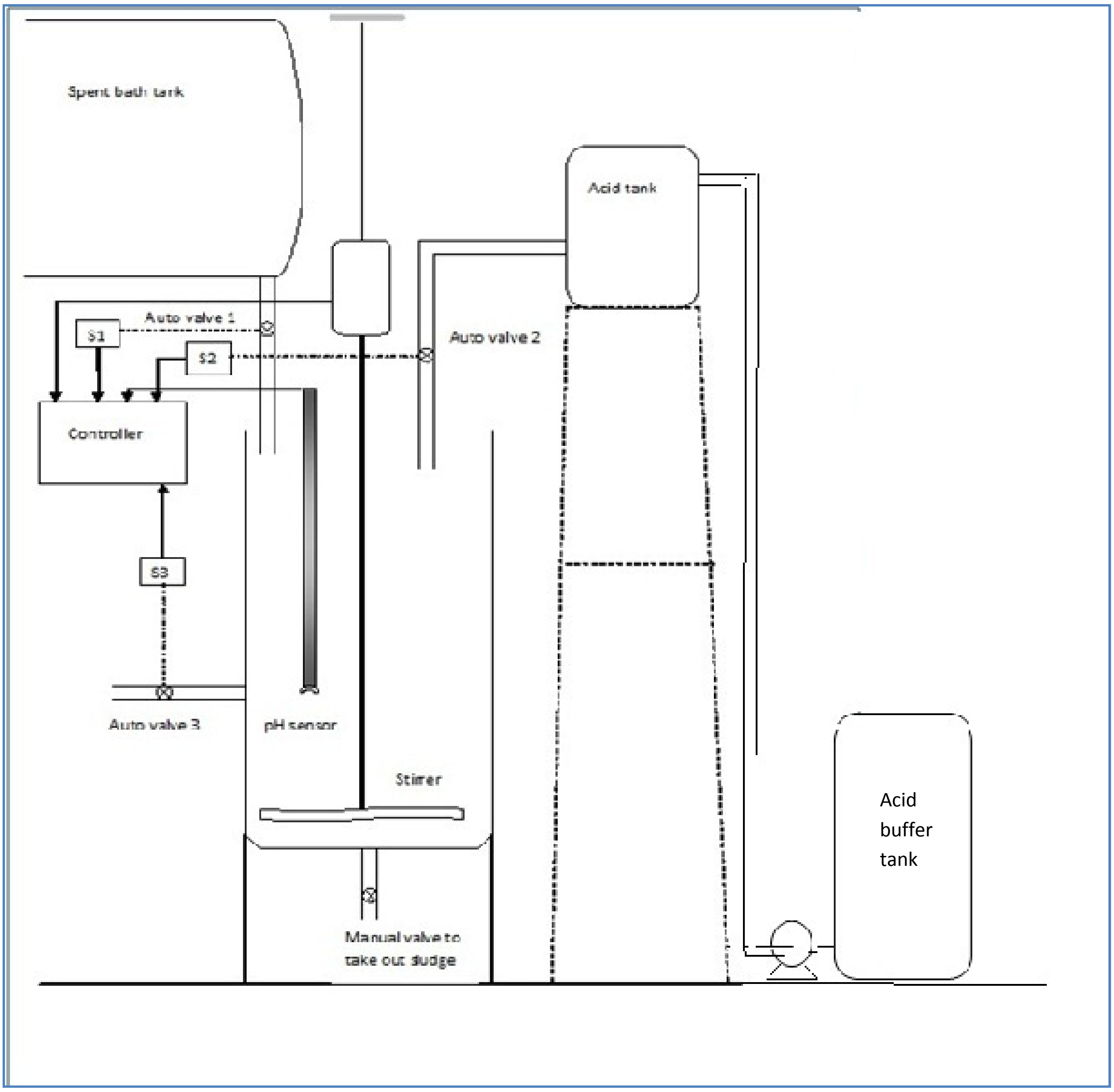


Fig. 15 Schematic diagram of plant (with automation)

The operation of stirrer was controlled by controller unit. When acid addition relay is on the stirrer starts automatically and it stops when acid addition stops.

The stand to keep the main tank was also prepared as per requirement. Its height was kept at an optimum distance so that it is easy to drain out the solid waste slurry from the bottom and at the same time it is not too high so that plant operation is easy.

The operation of the stirrer was kept manual and a separate switch was provided with VFD knob near the control panel of the pH monitoring and dosing system.

The valve at the bottom to take out solid waste from bottom was also kept manual so that it is only operated when sufficient amount of the same is accumulated.

Working of the plant:

The plant works automatically as per following sequence.

- When measure key is pressed spent bath in relay is on, fill time starts decrement.
- When fill time is over there is a delay in the form of hold time given for stabilization of pH.
- After hold time is over controller checks band of pH. (Set value of pH is 7 pH).
- Initially the pH value is basic (>8 pH), then acid in relay will on for control time then off and checks band acc to check time. (This will continuous if >8pH). When acid relay is on stirrer starts automatically.
- If acidic pH value (<6pH), then hooter relay will on and generates fault indication on lcd screen and stops cycle.
- If pH value in band (6<=pH<=8), then acid in relay will stop and solid residue settling time starts decrement. At this juncture stirrer will stop automatically.
- When settling time is over, clear solution out relay will be on and drain time starts decrement.
- After completion of drain time clear solution out relay will off and hooter relay will on to indicate completion of cycle and display message on lcd 'cycle over'.

Initially the control panel program has to be set and the time of filling the tank with spent has to be fit into the panel. For this time study is required. It was observed that the tank gets filled upto the mark in 3.0 minutes. After 3.0 minutes the spent bath addition valve

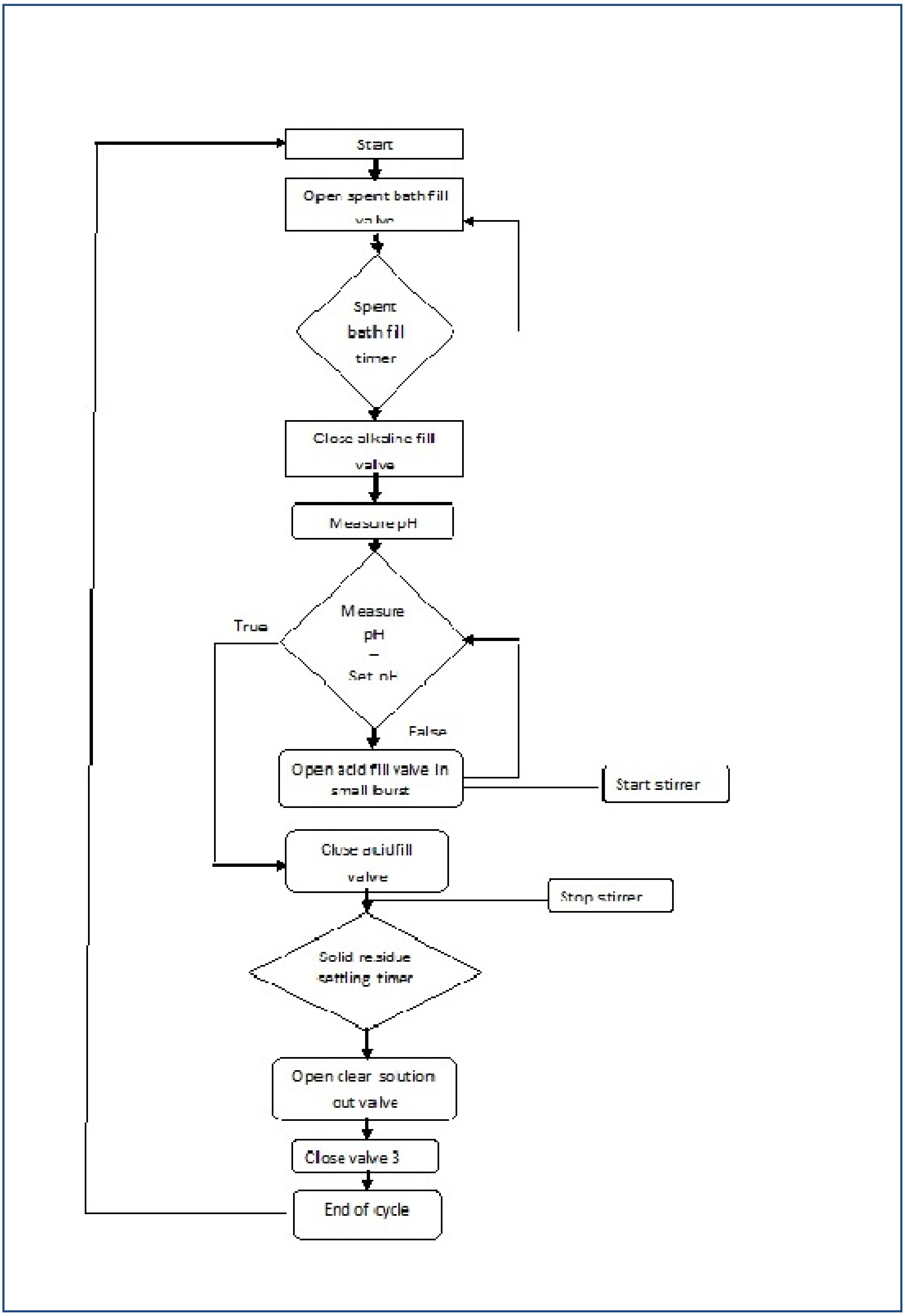


Fig. 16 flow sheet showing working stages

will stop automatically and acid addition valve is opened. At this moment stirrer is started automatically. After reaching pH = 7 the acid addition valve is automatically stopped, the stirrer gets stopped immediately and settling time timer is started. The settling time has to be fit into the panel of programmer which allows residue generated to settle. (5.0 minutes). After 5 min. the clear water out valve opens automatically and tank is emptied up to level of valve. Further time required for tank to empty clear solution up to level of clear water drain valve is also noted and is fitted into the panel. (3.0 minutes). On completion of set time one cycle is completed and automatically another cycle starts. The cycle is repeated till WR spent bath is available in the overhead tank. When the entire volume of overhead tank is treated there will be no spent bath in the over head tank and at that juncture the solid waste generating plant has to be stopped. The time required for one cycle is 15 minutes in which 150 lit of spent bath is treated. Entire volume (2400 lit for 800 kg machine) will require 2400/150 = 16 cycles. **Total time for entire batch of 2400 will be 16 cycles x 15 min = 240 min. = 4 hours.**

9.7 Analysis of clear solution

The supernatant clear solution drained out was analyzed for Total dissolved solids and chemical oxygen demand. Since the ethylene glycol is by product of weight reduction and is water miscible hence it goes with clear solution. This will contribute to COD. Further the acid neutralizes excess of NaOH as well as converts disodium phthalate into terephthalic acid. Thus NaCl is produce which will increase TDS of clear solution. The table 11 shows analysis of 5 samples analyzed.

Table 11

Sr no.	Sample	Spent bath TDS mg/lit	Spent bath COD	TDS mg/lit	COD mg/lit
1	P 1	99443	194000	75336	110000
2	P 2	129060	212000	95600	123000
3	S 1	173542	167200	135580	79040
4	S 2	180782	188150	139106	97111
5	P CWR	39229	81320	29276	44726

9.8 Solid waste generated

Solid waste generated from five different locations was as shown in table 12.

Table 12 solid waste quantity generated

Sr no	**Code of the process house**	**Quantity of solid waste generated**
1	P 1	80
2	P 2	70
3	S 1	65
4	S 2	240
5	P 1 CWR	55
	Total	**510**

The wet sludge collected from bottom of the tank was taken on bolting cloth and squeezed to remove excess water. Then it was spread on ground and dried in air.

9.9 Boiler stack analysis after charging with solid waste along with coal

The solid waste generated was in slurry form and was spread on a drying bed. The dried powder was mixed with coal with different ratio as follows.

1. Coal: solid waste :: 80:20 (830:170)
2. Coal: solid waste :: 65:35 (660:340)

Then above mixture was charged in a coal fired boiler of a local process house. A simultaneous monitoring of air pollution parameters were measured stack monitoring apparatus. The flue gas was passed through pre weighed thimble and suspended particulate matter was assessed. Similarly standard procedure to analyze Sox and Nox was followed.

Table 13 Boiler stack monitoring

Sampling	Fuel	SPM	SOX	NOX
1	Control monitoring only coal	117	51	4
2	Charged with Coal:waste mixture (65:35)	73	32	3.4
3	Charged with Coal:waste mixture (80:20)	54	26	2.6

Fig 17: image: control valve 2 for acid addition

Fig 18: Image: auto valve 3 for clear solution outlet

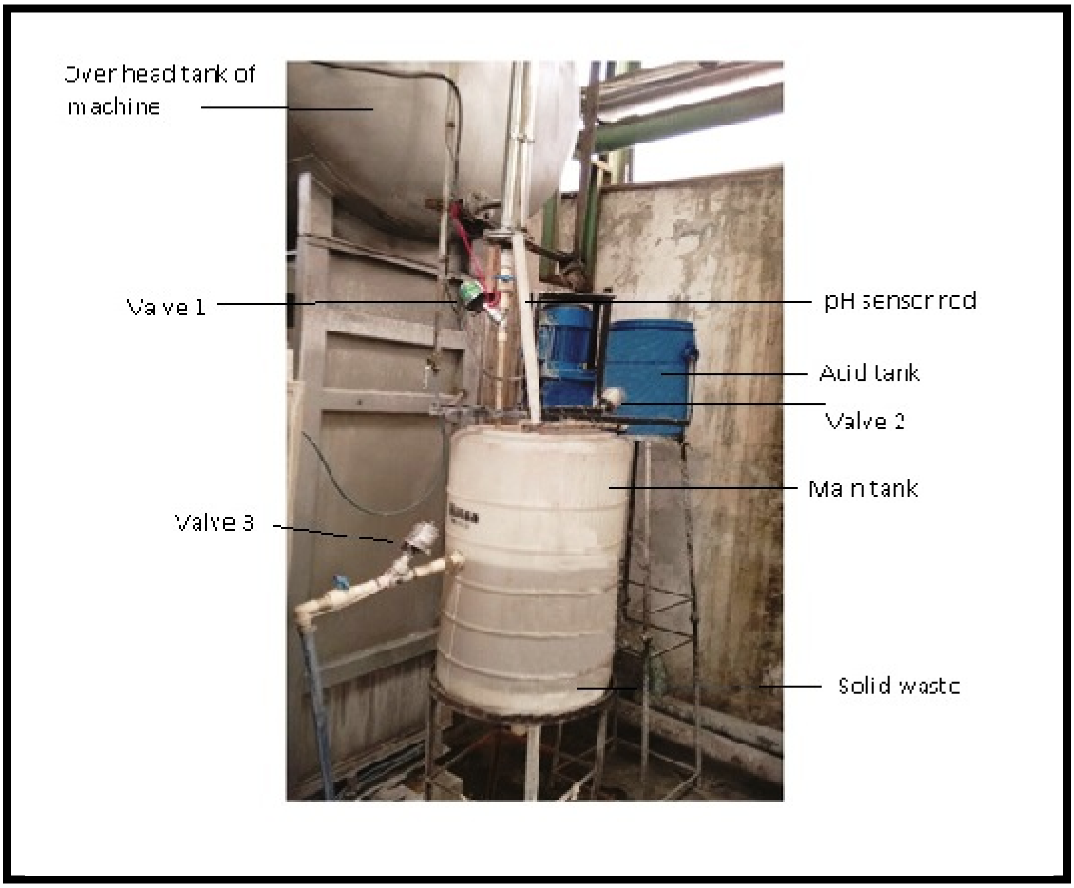


Fig. 19 image: view of the plant

Fig. 20 display of the control unit

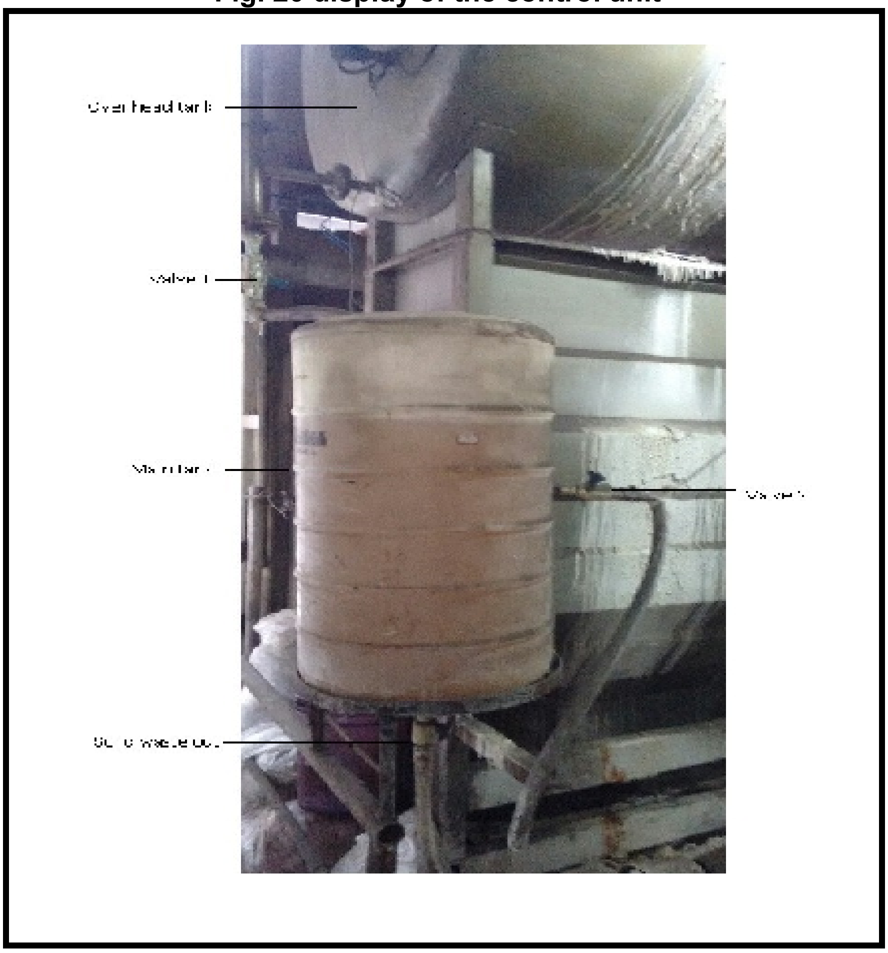


Fig 21: Manual plant

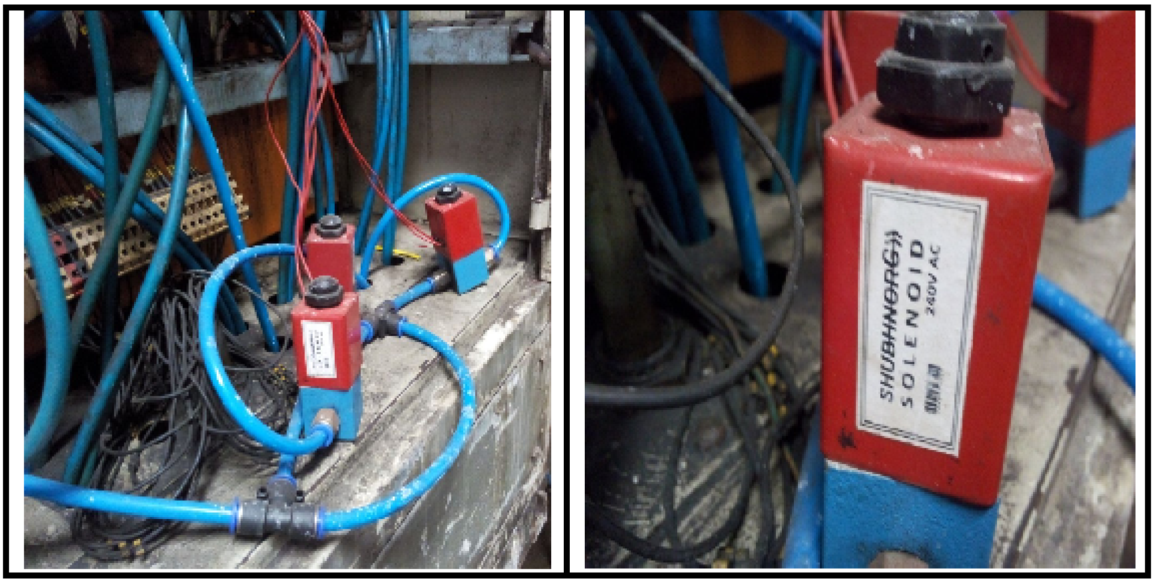


Fig. 22 Solenoid valve connected to controller unit and pneumatic valve

9.10 Cost economic aspects

The plant constructed in this project was only to demonstrate the technology. We have installed plants at different locations were only of 225 litre capacity. The reason behind keeping capacity to low volume was also because generally in a process house large available space near to the fabric processing machine is not available.

Cost of installation of plant

The cost can be worked out as follows

Table 14 cost of plant

	Item	**Price in Rs.**
1	main tank (Sintex, capacity 225 lit)	3000
2	Controller with pH sensor	75000
3	Control valve (pneumatic) 3 Nos	6000
4	Solenoid valve (3 Nos)	1400
5	Stirrer	2500
6	Acid tanks with pump	8000
7	Other (piping,stand, etc)	2500
	Total	**98400**

To generate solid waste from spent bath the only ingredient consumed is the acid. The commercial acid available is available at Rs.1.5 per Kg.

The cost of solid fuel used by process houses are coal or lignite. The coal may be Indian coal or an imported. The costs of these are as follows.

Table 15

	Solid fuel	**Current market price Rs/Ton***
1	Coal (Imported) GCV 5800 Indonesia, South Africa	5000
2	Lignite coal (GCV 2800 to 3200)	2800

(* prevailing market price of Surat as on 1st January, 2015)

From our study we have found following figures for treatment of 100 liters of spent bath,

For 100 liters we need on an average

- 8 liters of acid (28%)
- 4 kg of waste generated

(See table no 10 on page 31)

Extrapolating this for 2400 liters of batch we will require 192 liters of commercial acid (28%). And will be able to generate 96 kg of solid waste. Above yield is based on the assumption that the spent bath has been collected after at least 8 reuse cycles.

Cost of acid required to generate solid waste would be

Liter of acid x price

= 8 x 1.5 = 12 Rs/4kg

i.e. 3 Rs/kg

The energy consumption

The energy consumed in running of the plant was the electrical energy for running controller and for running stirrer. The stirrer was of 0.5HP. the conversion for H.P. into KW is 1 H.P. = 0.746 kW. Therefore for 0.5 H.P will be 0.373 KW. The consumption of stirrer would be 0.373unit/hour. The unit cost at present in Surat industry is Rs 7.5/unit. The stirrer is not running continuously but only during acid addition. i.e in one cycle it is running for 7.5 minutes. That is 50% time. Thus for complete treatment of 2400 lit batch it takes 4 hours time therefore it will run for 2 hours. At this rate it would consume 0.373 x 2 = 0.746 units. i.e. 0.746 x 7.5 = 5.6 Rs. Thus for entire batch generating 96 kg waste therefore electrical consumption per kg of waste generated would be 5.6/96 = 0.058 Rs/kg.

Total running cost of the plant is as follows.

Table 16 Running cost of plant

Cost	**Cost Rs/kg**
Chemical cost	3.0
Energy cost	0.06
Total	**3.06**

The pollution load analysis

To assess the pollution load reduction we have measured initial COD value of Spent bath before treatment. Subsequently the COD value of clear solution was measured after treatment in the plant, the results are given in table 17

Table 17 analysis of pollution in terms of COD

	COD of spent bath (a)	**COD of clear solution (b)**	**COD reduction (a – b)**	**% reduction**
1	242000	110000	132000	54
2	312000	123000	189000	60.5
3	167200	79040	88160	52.7
4	188150	97111	91039	48.38
5	81320	44726	36594	55

The other pollution parameter needs consideration is the Total Dissolved Solids (TDS). As we add Hydrochloric acid to the spent bath NaCl is generated. Apparently it looks that clear solution drain should have more TDS. However when we compare TDS of original spent bath with that of clear solution drain there is decrease in TDS value. This is because of the isolation of di sodium terephthalate which is soluble in spent bath and it contributes to spent bath TDS. Hence we get about 21 to 26 % reduction in TDS by this process. See following table 18.

Table 18 analysis of pollution in terms of TDS

	TDS of spent bath (a)	TDS of clear solution (b)	TDS reduction (a – b)	% reduction
1	99443	75336	24107	24
2	129060	95600	33460	26
3	173542	135580	37962	21.8
4	180782	139106	41676	23
5	39229	29276	9953	25

10. Detailed analysis of results indicating contributions made towards increasing the state of knowledge in the subject:

10.1 Characterization of weight reduction spent bath

It has been practice to reuse the spent reduction bath after the process is completed in a fabric weight reduction machine. During the course of this project study we have observed that no standard practice for reuse of spent caustic bath is followed by the local industry. In many units the reuse cycle is continued for several days without completely draining the spent bath. Hence the samples collected from various units shows large amount of variation in the properties when it was analyzed in the laboratory.

To see what happens to the spent bath properties at each reuse cycle, samples were collected for every reuse cycle starting from fresh bath up to 20th reuse cycle, in one selected process house. The samples drawn were tested in the laboratory and the results for various parameters at the end of each cycle are given in table no.2 on page 21. To see the pattern of change in properties and to see the pattern of accumulation of impurities a plot of COD value vs no of cycles was drawn as shown in following figure 21.

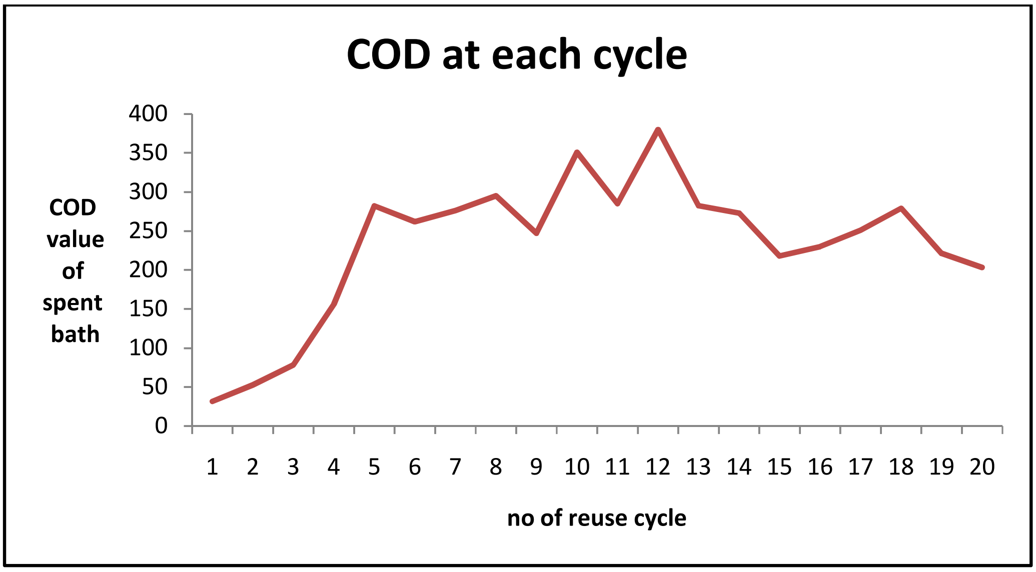


Fig. 21

The Chemical Oxygen Demand, COD is the measure of pollution load and is direct indication of impurities generated. It can be seen from the plot that COD value increases with no of cycles up to 10th cycle and then COD value becomes range bound, i.e it fluctuates around 275000 mg/lit.

Similarly a plot of TDS vs no of reuse cycles was drawn as shown in following figure 22.

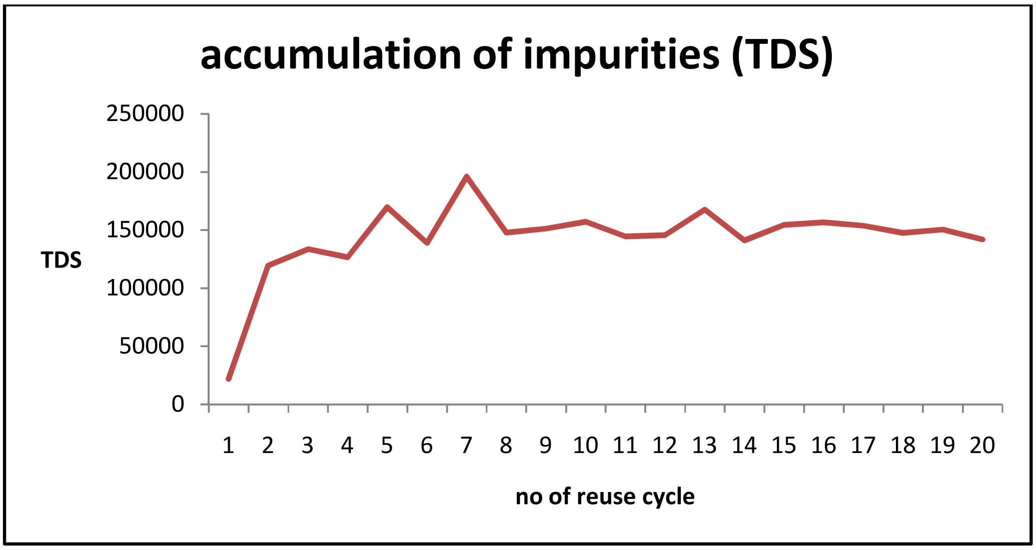


Fig. 22

Here also the TDS value becomes range bound after reuse cycle no 9 and remains around 150000 mg/lit.

This exercise has revealed important results based on which a guideline for reuse of weight reduction bath can be set. It appears that the WR bath can be reused for about 8 to 10 cycles only and prolong recycling would be meaningless. For this project it suggest that weight reduction spent bath can be taken after 8 to 10 cycles of reuse so that a substantial amount of solid waste is obtained.

The pH of spent bath obtained from various sources was almost similar i.e. around 13.0. this is because the level of excess alkali remained identical as supplementary amount of caustic soda was added after each cycle.

The Total dissolved solids (TDS) increased as the dissolved polyester component contributed to the value. The total suspended solids were found in small amount is may be due to impurities found in fabric including soil and other adventitious matter.

The chlorides and sulphates found are possible only due to raw water. Small amount of presence of iron is possibly due to contamination.

The COD value which is direct indication of pollution generated is very high after 10th cycle. The terephthalic acid is main ingredient contributing to this.

10.2 Characterization of solid waste

The nature of solid waste generated is largely organic with some amount of inorganic impurities. In the organic part it is mainly Terephthalic acid or its sodium salt. Hence the GCV of the solid waste found was very good in the range of 3700 to 4400. This is far better than lignite and near to good quality coal. Further quality of solid residue was very good in case of samples obtained from continuous weight reduction range (CWR). The GCV found was in the range of 4700 to 5200 and the ash content was comparatively very less in the range of 5 to 6%. This is because in CWR they follow pad-alkali-steam process. In this sequence there is no reuse and hence accumulation of impurities was not there.

In case of samples obtained from process houses following soft fabric weight reduction machine the quality of solid waste generated was inferior in terms of GCV and ash content. The GCV in this case was found in the range of 3900 to 4400. The ash percentage was found in the range of 14 to 17%. This was high compared to values obtained with CWR. This is because at every reuse cycle of weight reduction there is accumulation of fabric impurities which leads to increase in ash content and proportionately decrease in GCV.

Since the major portion of the solid waste is Terephthalic acid the burning characteristic of solid waste would be that of TA. TA has melting point of 300ºc and hence it is expected that the product would burn easily in boiler. The solid residue was also subjected to DSC (Differential scanning calorimeter). The plot is as shown in Fig. 13 on page 28. The comparison suggests that DSC profile of solid residue is similar to that of Terephthalic acid.

Terephthalic acid has sublimation property and the sublimation starts at 300°c. Though the GCV is high the fixed carbon is less i.e. around 11%. This may be because of sublimation property of terephthalic acid.

10.3 Solid waste generation

The manual plant was installed at 5 different places. The weight reduction bath was taken in the tank and solid residue was generated. The sludge was periodically removed and dried by spreading in open air. When the automation of plant was done at one of the above process houses solid waste was also generated from there. The manual procedure is tedious and cannot become viable.

The automation of the plant made it more user friendly. The worker working on weight reduction machine has to start the plant once the spent bath is lifted in the overhead tank of the machine. From the study of characterization of spent bath at different reuse cycle it is concluded that optimum quantity of the waste can be generated after 8 to 10 reuse cycle. Hence the operator has to start the automatic system after lifting the spent on to overhead tank. The total spent bath in the overhead tank is about 2400 lit. The proposed plant with 225 lit capacity takes 15 minutes for completion of one cycle. In one cyclie 150 lit of spent bath is treated. Therefore it will require completion of 16 cycles to completely treat total spent bath. i.e. about 4 hours. The plant capacity can be slightly increased to reduce time required for complete conversion of one batch into waste.

Generally when weight reduction process is over the spent bath is lifted to overhead tank. After this the fabric in the machine is washed with hot water and wash liquor is drained. Again the machine is filled with water and oxalic acid to neutralize residual alkali from fabric and the wash liquor is drained. Then again fabric is rinsed with water. Then unloading of batch and fresh loading of another batch takes place. For doing all this activity about 2 ½ hours time is required. In 12 hours shift time only two batch per machine is achieved. So whenever it is decided to generate solid waste plant operator has to start the plant after spent bath is lifted to overhead tank. After all spent bath is treated next batch is started with fresh alkali bath.

10.4 Cost economic aspects

The cost of construction of plant is Rs. 1.05 lakh which is about 6.5% of the total machine cost (the new machine cost about 16 lakhs for 800 kg fabric loading capacity) and this is affordable. The breakup of cost of generating solid waste is as follows

i) Chemical cost: 3.00 Rs/kg
ii) Energy cost:` 0.06 Rs/ kg

So the major cost of generating waste is the chemical cost.i.e. Cost of Hcl consumed per kg of waste. This comes to about Rs. 3/- per kg. This is very near to the cost of lignite. But the average GCV we obtained from the study is 4000 which is far better than the GCV of lignite which is about 2800 to 3200 on receivable basis.

The total waste generated per one batch is about 96 kg for 800 kg capacity machine having quantity of lifted bath 2400 lit. We are recommending the waste generation at every 8th reuse cycle. No of batches per month per machine is 4 x 28 = 112. Therefore we can have 14 times waste generating treatments per machine per month.

With this we can generate 14 x 96 = 1344 kg of waste per month per machine. Putting price of solid fuel with GCV 4000 at 3.5 Rs/kg the value of waste would be Rs. 4704. On an average a process house in Surat cluster has 2 to 5 weight reduction machine depending on production capacity of a process house. Thus waste can be generated for process house with two machines would be (1344 x 2 = 2688 kg) and for process house with 5 machines would be (1344 x 5 = 6720 kg) i.e. 2.6 to 6.7 tons per month per process house if proposed plant is run as recommended.

Here in this study we have connected one plant with one machine but it can be easily connected with 2 or more machines as process of weight reduction is batch wise and plant is run only after 8 reuse cycles. Hence waste generating program can be adjusted so that waste generating plant is utilized effectively. The payback period on return of investment would therefore depend on number of machine connected to one plant. Following table shows payback period for different situation.

Table 19 payback period

Waste generating plant connected to	**Total waste generation/month Ton**	**Value of waste /month @ Rs3500/Ton**	**Payback period in month @ total plant cost Rs. 1 lakh**
One WR machine	1.3	4550	22
Two WR machine	2.7	9450	10.5
Three WR machine	4.0	14000	7.1

So far as pollution load reduction is concerned the by the developed process one can reduce COD load due to weight reduction by about 54%. The reduction in pollution is due to removal of terephthalic acid along with some oligomers in terms of COD value. Also there is about 21 to 26% reduction of pollution in terms of TDS. This is because of isolation of terephthalic acid as solid waste which was earlier soluble in its sodium salt form.

10.5 Utilization of waste as fuel

We have taken trials on waste generated during the course of study. For industrial trials one requires huge quantity of fuel to be charged in boiler. The quantity generated was not enough so only two trials were possible that to after mixing with coal in two different proportions. While charging in boiler and simultaneously monitoring air pollution parameter we found no significant increase in SPM, Sox and Nox values. The results show that the waste would not be harmful and hazardous as its major contains basic monomer which contains only carbon, hydrogen and oxygen in its atom. The terephthalic acid the major component of the waste has melting point of 300°c and it has sublimation property. Before the industry starts utilizing the waste as fuel the consent will be required from local pollution control authority. It seems most likely that product will pass the approval procedure.

11. Conclusions summarizing the achievements and indication of scope for future work:

11.1 Summary of achievements

Weight reduction of polyester is very important process for decentralized synthetic fiber fabrics processing sector. The average weight reduction carried out by synthetic filament fabrics intended for saree and dress material is in the range of 10 to 35%. The process generates pollution in form of byproducts of the process. At the end of each weight reduction process cycle the spent bath is reused for several cycles. These byproducts on several reuse cycle is accumulated as impurities in spent bath which also affects subsequent processing quality.

In this project we have designed a process to utilize weight reduction process spent bath where in a major component of byproducts i.e. Terephthalic acid along with other impurities is isolated as solid waste. The waste has high gross calorific value. The waste has been utilized as fuel for boilers. By following the process one can generate good quality fuel from waste which would otherwise create pollution.

By isolating solid waste there is benefit in terms of reduction in terms of pollution load reduction. There is about 54% reduction in COD value and 21 to 26% reduction in TDS value. So along with energy generation pollution load reduction is also achieved.

11.2 Conclusion

It has been concluded that

1. The weight reduction produces impurities at each stage of reuse cycle and it is meaningless to continue reuse cycle beyond 8th cycle.
2. The waste generation process if followed as suggested in this study can help generate solid waste of about 100 kg daily at a cost of about 3 Rs/kg
3. The cost of constructing the system would be Rs 98400 with payback period of 7 to 10 months
4. The process will help reduce pollution load in terms of COD and TDS. This will not only help in reducing water pollution and solid waste disposal but will improve process efficiency and subsequent improvement in quality of printing.

11.3 scope for further work

The present work has shown the way to generate solid waste utilizing spent bath of weight reduction process. The work can be further carried out to link 3 machines at a time and the automation can be made PLC based controlled in efficient manner. More study is required to evaluate air pollution parameter by generating sizable quantity of solid waste. Industrial trials on large scale are necessary.

12. S&T benefits accrued:

(i) List of Research publications

S.No.	Authors	Title of paper	Name of the Journal	Volume	Pages	Year

(ii) List of paper presented

The work progress has been presented to Research advisory committee of MANTRA comprising of selected council members and industry representative in July, 2014.

(ii) Manpower trained on the project

a) Research Scientists or Research Associates:

B. C. Chauhan

b) No.of Ph.D. produced:

N.A.

c) Other Technical Personnel trained

N.A.

(iii) Patents taken, if any:

Will be applying for the process developed

13.Financial Position

STATEMENT OF EXPENDITURE

13. Financial Position

Sr.No.	Financial Position / Budget Head	Funds Sanction	Expendtiure	% of Total Cost	Remarks
1	2	3	4		
1	Salaries / Manpower costs	19,36,000	30,80,237	65	
2	Consumables / Supplies & Materials	5,80,000	4,01,423	9	
5	Overheads	1,00,000	58,799	1	
4	Other, if any	4,50,000	7,84,509	17	
5	External pilot / bulk scale trial	8,00,000	8,00,000	17	
6	Equiptment	8,50,000	5,54,571	12	
	Total	47,16,000	56,79,539	100%	

14. Procurement/ Usage of Equipment

a)

Sr. No.	Name of Equipment	Make/Model	Cost (FE/Rs)	Date of Installation	Utilisation Rate (%)	Remarks regarding maintenance/ Breakdown
1	Digital Bomb Calorimeter	Hindustan Apparatus Hamco 6 D	242659.00	22.10.14	100	Nil
2	Carbon Residue Apparatus	Hindustan Apparatus Hamco (as per ASTM D 524)	41398.00	22.10.14	100	Nil

3	Muffle furnace	Hindustan Apparatus Hamco 19 B	128611.00	22.10.14	100	Nil

b) Plans for utilizing the equipment facilities in future:

the equipments will be utilized for routine testing of coal, lignite, sludge, etc in chemical testing laboratory

Name and Signature with Date

a. ________________________

(TRA)

b. ________________________

Annexure - V

Man Made Textiles Research Association, Surat

FINAL STATEMENT OF EXPENDITURE

1 Sanction Letter / Order no. and date of sanctioning the project : 1 No. 10/17/2012-TUFS Dt. 01.02.2013

2 Total Project Cost : Rs. 47.16 Lacs
(Utilization of spent weight reduction bath for pollution reduction and energy generation in decentralized textile processing sector
(Waste to energy approach)
(Sanctioned / Revised Project Cost, if applicable)

3 Date of Commencement of Project : 01.02.2013

4 Date of Completion of Project : 01.02.2015

5 Grant received in each year (financial year) :

a. 1st Year { 2012 - 13 } : Rs. 14.15 Lacs

b. 2nd Year { 2013 - 14 } : Rs. - Lacs

d. Interest, if any : Rs. - Lacs

Total (a+b+c+d+e) : Rs. **14.15 Lacs**

** Government Share : Rs. 35.37 Lacs

STATEMENT OF EXPENDITURE

Utilizatin of spent weight reduction bath for pollutin reduction & energy generation in decentralized textile processing sector (Waste to energy approach)

Sr.No.	Sanctioned Heads	Funds allocated (indicate sanctioned or revised)	Expenditure Incurred				Total	Balance, if any	Remarks
			1st Year	2nd Year	3rd Year	4th Year			
			(01.04.12 to 31.03.13)	(01.04.13 to 31.03.14)	(01.04.14 to 28.02.15)				
(I)	(II)	(III)	(IV)	(V)		(VI)	(IV+V+VI)		
1	Salaries / Manpower costs	19,36,000	4,01,546	21,65,349	5,13,342	-	30,80,237	(11,44,237)	
2	Consumables / Supplies & Materials	5,80,000	32,029	1,72,988	1,96,406	-	4,01,423	1,78,577	
3	Travel	1,00,000	471	2,508	55,820	-	58,799	41,201	
4	Other Cost and Contengiency Expenses	4,50,000	64,504	5,83,845	1,36,160	-	7,84,509	(3,34,509)	
5	External pilot / bulk scale trial	8,00,000	-	-	8,00,000	-	8,00,000	-	
6	Equiptment	8,50,000	-	-	5,54,571	-	5,54,571	2,95,429	
	Total	47,16,000	4,98,550	29,24,690	22,56,299	-	56,79,539	(9,63,539)	

Amount to be ~~refunded~~ / reimbursed (whichever is appropriate) : Rs. 21.22 Lacs

Name and Signature of TR A

Signature of Competent financial/audit authority (with Seal)

MR.M.G. PARIKH
S.S.O. – II

DR.S.K. BASU
Director, MANTRA
(Surat)

Annexure-VI

UTILISATION CERTIFICATE

FOR THE FINANCIAL YEAR - (ENDING 31ST MARCH)

1. Title of the Project/ Scheme : (a) Utilization of spent weight reduction bath for pollution reduction & energy generation in ecentralized textile processing sector (Waste to energy approach).

2. Name of the Institution : M A N T R A.

3. Principal Investigator : Mr.M.G.Parikh

4. Department of Ministry of Textiles sanction order No & date

   Sanctioning the project : 1. No.10/17/2012-TUFS Dt.01.02.2013.

5. Head of account as given in the original sanction order: As per Statement attached.

6. Amount brought forward from the previous Financial year quoting reference letter no and date in which the authority to carry forward the said amount was given
   i. NIL
   ii.
   iii..

7. Amount received during the financial year i. 14.15 Lacs (2012-13)

8. Total amount that was available for expenditure (excluding commitments) during the financial year (Sr. No. 6+7) 14.15 Lacs

9. Actual Expenditure (excluding commitments) Incurred during the financial year Rs. 56.80 Lacs

10. Balance amount available at the end of the financial year : Nil

11. Unspent balance refunded, if any (please give details of cheque no etc.) : N.A

12. Amount to be carried forward to the next financial year (if applicable) : N.A

UTILISATION CERTIFICATE

Certified that out of Rs. **14.15** Lacs of grants-in-aid sanctioned during the year **2012-13**, in favour of **Man Made Textile Research Association.** under this Ministry/ Department letter/ order No **10/17/2012-TUFS** dated 0**1.02.2013** Rs **Nil** on account of unspent balance of the previous year, a sum of Rs. **14.15** has been utilised up during the F.Y 2012-13 for the purpose of **activity** for which it was sanctioned and that the balance of Rs **Nil** remaining unutilised at the end of the year has been surrendered to Government (vide Challan no ______ dated ______) / will be adjusted towards the grants-in-aid payable during the next year.

Signature of PI	Signature of Head	Signature of Manager Accounts the Institute
Date	Date	Date

(To be filled in by ……)

Certified that I have satisfied that the conditions on which the grants-in-aid was sanctioned have been fulfilled/ are being fulfilled and that I have exercised the following checks to see that the money was actually utilized for the purpose for which it was sanctioned :-

Kinds of checks exercised.

1.
2.
3.
4.

Signature : ________________

Designation:_______________

Date:_____________________

P A M C

COMMERCIALIZATION PLAN

1) Name of the project:

Utilization of spent weight reduction bath for pollution reduction and energy generation in decentralized textile processing sector (Waste to energy approach)

2) Date of start 01.02.2013

Date of completion 1.02.2015

3) Type of project:

Applied research

4) Technical knowhow of the product/process developed

Process to generate solid waste from spent weight reduction bath for pollution reduction and energy generation is developed. A plant has been designed and developed and its working has been established.

5) Whether patentable

yes

6) If yes, tentative time to obtain the intellectual property rights (IPR)

3 years

7) Name of the Industry partner

Siddhivinayak Knots and Prints Pvt. Ltd. , Surat

8) Whether Industry partner is willing to commercialize the product outcome

Industry partner will help MANTRA to develop linkage to commercialize the process developed.

9) If yes, please give details of arrangements made

Not applicable

10) Tentative date of commercialization

Six months after completion of the project

11) Any other relevant information

Nil