JICA-SMEDA

ENERGY EFFICIENCY MANAGEMENT PROJECT FOR

INDUSTRIAL SECTOR IN PAKISTAN

BEST PRACTICES

For Energy Efficiency in Industrial Sector in Pakistan Based on Japanese Best Practices

February, 2017

Prepared by

Energy Efficiency Management Project, JICA

List of Best Practice of EEPM

<u>E-1 Proper Voltage Level</u>

1. Theory/Principle

In Pakistan voltage level of factories are generally low and fluctuating. The main causes are low and fluctuating voltage at power receiving point and small factory cable size which causes big voltage drop on the cable. Allowable voltage level for electrical equipment is generally ±5% of equipment rated voltage (sometimes ± 10%). In case voltage imposed on electrical equipment is beyond allowable voltage level, efficiency of the equipment will be lower and equipment life will be also shortened.

2. Outline

2-1 Low level of receiving voltage and equipment voltage (A Factory)

Electrical data @ power receiving point, Oct. 2016

	V	A	PF (%)	kW	Thd% VL3
MAX	388.0	736.0	99.1	439.9	11.6
MIN	362.3	109.8	80.7	67.2	4.0
AVG	373.0	489.7	94.9	299.0	8.1

Electrical data @CNC input, Oct. 2016

	V	A	PF	KW	Thd% V L3
MAX	352.0	51.8	137.7	23.8	10.9
MIN	337.9	10.9	27.1	-8.3	4.1
AVERAGE	346.5	12.8	37.2	2.8	8.4

Low level: 337.9/380 x 100 = 89%

1) Improvement proposal

To increase voltage by increasing taps of receiving transformer

According to the company CEO's strong request based on above Improvement proposal, LESCO increased receiving transformer taps during the Audit.

2) Results

3-PHASE VOLTAGES AFTER TAP CHANGE

	R-S (V)	S-T (V)	T-R (V)
WAPDA voltage at main receiving point before IF startup	415	415	415
WAPDA voltage at main receiving point after IF startup	407	404	410
At Induction Furnace	400	400	392
CNC main supply	400	400	397
CNC 2 transformer input	396	396	399
CNC 2 transformer output	209	207	208
CNC 3 AVR input	398	399	400
CNC 3 AVR output	385	380	380

<u>**Low voltage situation on whole factory electrical system was solved.**</u>

2-2 High and low level of receiving voltage (B Factory)

Electrical data @ Hydraulic Pump feeder, Sep. 2015

	V	A	PF (%)	kW
MAX	427.0	11.4	85.0	6.9
MIN	402.6	10.8	84.0	6.6
AVERAGE	413.1	11.1	84.4	6.8

High level : 427/380 x 100 = 112%

Electrical data @ AVR input, March 2016

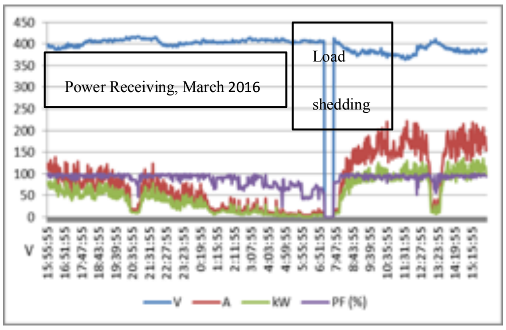
	V	A	PF (%)	kW	ThdV L3 (%)
MAX	372.4	27.0	174.5	15.3	5.9
MIN	351.3	2.2	0.0	-6.9	4.5
AVERAGE	363.5	7.7	82.5	3.5	4.9

Low level : 351.3/380 x 100 = 92%

1) Improvement proposal

a) Monitoring daily receiving voltage and keeping the record

b) Monitoring 24 hours receiving voltage once a month and keeping the record



	V-n	V-V	A	kW	PF (%)
MAX	241.0	417.5	221.9	136.1	100.0
MIN-1	222.8	385.9	3.3	1.0	23.7
MIN-2	210.2	364.1	11.4	6.6	51.7
AVERAGE-1	233.5	404.5	47.0	30.6	86.3
AVERAGE-2	222.0	384.6	141.7	87.5	92.6

In case receiving voltage fluctuation is too big and beyond allowable equipment voltage level, factory management should discuss with power company for improvement based on recorded voltage data of above a) and b).

2-3 Effectiveness of AVR (Automatic Voltage Regulator) (B Factory)

In case voltage level is high or low, AVR is effective for keeping voltage within setting range. So AVR should be installed for important equipment/ system such as CNC machines.

Electrical data @ AVR input, March 2016

	V	A	PF (%)	kW	ThdV L3 (%)
MAX	372.4	27.0	174.5	15.3	5.9
MIN	351.3	2.2	0.0	-6.9	4.5
AVERAGE	363.5	7.7	82.5	3.5	4.9

Electrical data @ AVR output, March 2016

	V	A	PF (%)	kW	ThdV L2 (%)
MAX	377.9	26.4	194.6	15.4	5.8
MIN	359.9	2.2	0.0	-7.1	4.4
AVERAGE	370.5	7.7	83.0	3.5	5.0

AVR output voltages are raised to approach to setting voltage of 380V in spite of lower voltage.

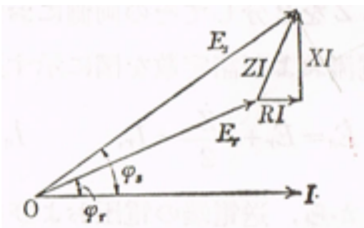
<u>E-2 Power Factor Improvement</u>

1. Theory/Principle

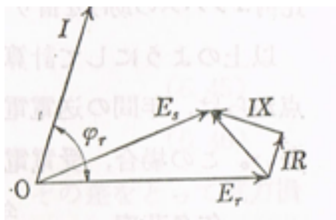
In Pakistan power factor improvement capacitors are installed at power receiving point for avoiding low power factor penalty (<0.9) by power company. For avoiding the penalty, factories tend to install excess capacity of capacitors. But if automatic power factor controller is not installed or doesn't function properly, excess capacity of capacitors causes leading power factor ("- "values). In case of leading power factor, following disadvantages occur.

1) Leading reactive current generates unnecessary energy loss.
2) Leading power factor ("-"values) seems to be converted into lagging power factor ("+" same values) in Pakistan. In this case higher leading power factor (PF (%)) is equivalent to lower lagging power factor (Pf (%)). Absolute values may be considered by power companies. --- Low power factor penalty is imposed if total power factor is less than 0.9.
3) High leading power factor may cause higher receiving voltage (Er) rise than source voltage (Es), which may damage electrical equipment in factories.

Lagging power factor: Er < Es



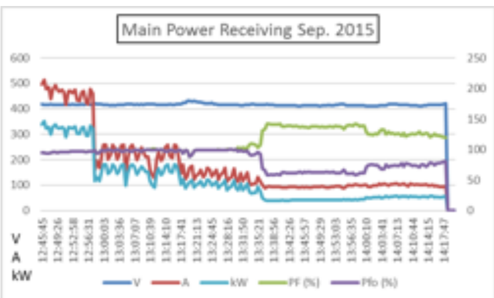
Leading power factor: Er > Es

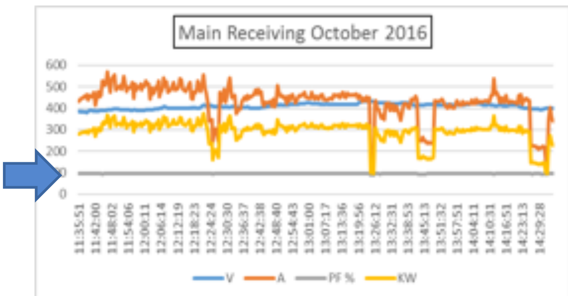


2. Outline

(1) A Factory

On Base Line Audit in September, 2015, power factor was leading on low load since automatic power factor controller didn't work properly. (PF is shown more than 100%.) Average power factor (Pfo) was 83.7%, low. The factory replaced the controller and set parameters properly based on JET advices. Power factor value was confirmed appropriate on the 3rd Audit in July 2016.



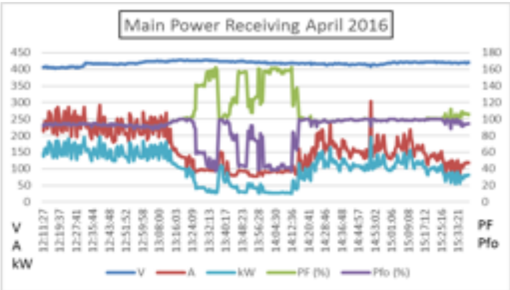


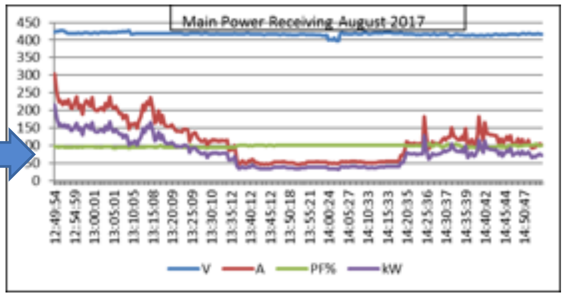
Data until 14:18:17					Sampling time :30se	
	V	A	PF (%)	Pfo (%)	kW	ThdV L3(%)
MAX	431.6	513.6	142.1	100.0	350.1	5.4
MIN	410.5	89.4	88.7	57.9	39.1	2.0
AVERAGE	416.3	178.4	114.1	83.7	115.5	3.5

	V	A	PF %	KW	Thd%V L3
MAX	433	571.1	97.4	377.2	4.98
MIN	380.2	144.5	90.1	97.5	1.73
AVG	409.1	430.5	96.1	292.8	3.66

(2) B factory

On 2nd Audit in April 2016, power factor was leading on low load since automatic power factor controller was not installed. (PF is shown more than 100%.) Average power factor (Pfo) was 87.3%, low. The factory installed automatic power factor controller and set parameters properly based on JET advices. Power factor value was confirmed appropriate on the 3rd Audit in August 2016.





					Sampling 30sec	
	Volt	Amp	PF%	Pfo (%)	kW	THD L3 (%V)
MAX	428.2	303.0	162.7	100.0	196.7	2.3
MIN	403.0	76.6	87.7	37.3	25.5	1.1
AVERAGE	418.4	159.2	107.4	87.3	104.1	1.6

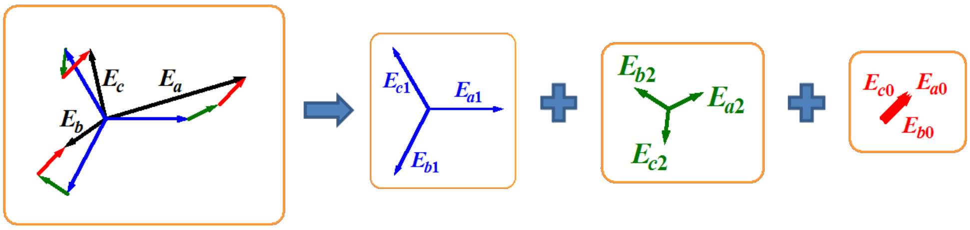
					Sampling 30sec	
	Volt	Amp	PF%	Pfo (%)	kW	THD L2 (%V)
Max	427.1	303.2	105.2	100.0	216.1	3.9
Min	396.6	45.5	88.6	88.6	32.4	1.3
Average	417.2	114.9	97.6	97.2	80.1	2.4

E-3 Rectification of Phase Imbalance

1. Theory/Principle

   (1) Method of Symmetric Coordinate

   Any type of three phase imbalance situation (Voltage, Current) can be described by summation of three type of vectors.



Imbalance (Black) Positive Phase Negative Phase Zero Phase

- Zero phase appears only at earth leakage accident.
- Usual Imbalance situation is described by summation of Positive Phase and Negative Phase.

(2) Problem

Imbalance current (negative phase current) causes excess increase of temperature, noise, vibration, decreasing efficiency, etc.

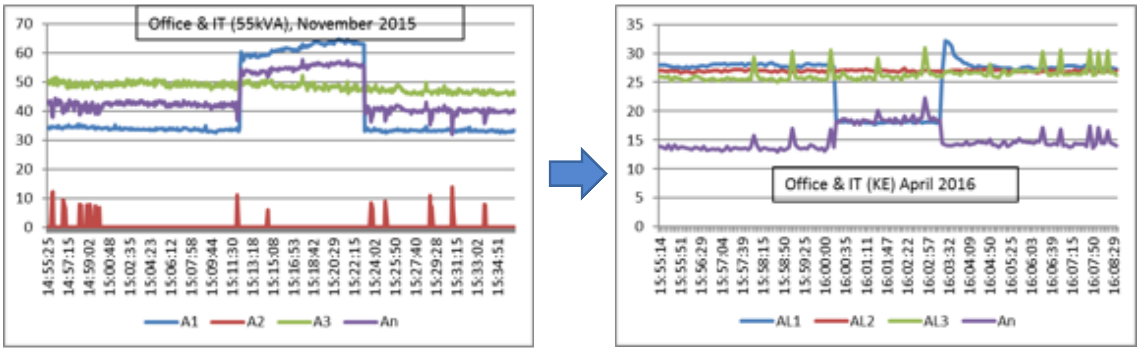
(3) Solution/countermeasures

- Transformer taps shall be properly set.
- Generator 3 phase voltage shall be properly set.
- Single phase load (lighting, heaters, rectifiers, office/laboratory equipment, etc.) shall be equally distributed to each three phase.
- Open-phase operation shall be avoided.
  (Open phase occurs because of blowing fuses, malfunction of disconnecting switches, circuit breakers, etc.)

2. Outline

(1) Current phase imbalance

On Base Line Audit in November 2015, current phase imbalance was very poor, especially small A2 phase current and big neutral current. The factory rearranged single phase Office & IT equipment. Current phase balance was confirmed to be improved on the 2nd Audit in April 2016.

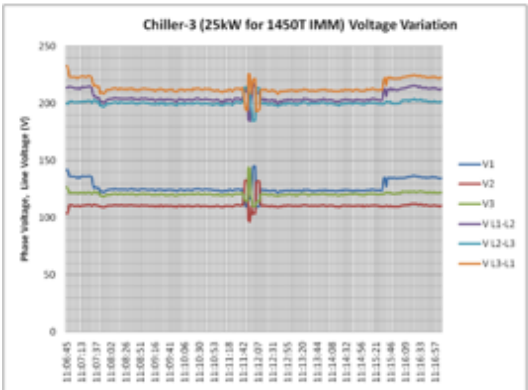


	A1	A2	A3	An	Imbalance (Av)
MAX	64.8	13.8	52.5	57.8	61.3%
MIN	32.5	0.0	45.5	32.0	98.5%
AVERAGE	41.2	0.4	48.4	44.9	30.0

	A1	A2	A3	An	Imbalance (Av)
MAX	32.2	27.4	31.0	22.3	2.5%
MIN	17.8	26.6	24.9	12.9	2.6%
AVERAGE	25.6	27.0	26.3	15.2	26.3

(2) Voltage phase imbalance

On former audit in November 2010 voltage phase imbalance was very poor. After investigation, it turned out voltage taps of unit transformer for chilling unit were set wrongly. Voltage phase balance was rectified by setting the transformer taps correctly.



at 11:06:50 : V1 142.2(V), V2 103.8(V), V3 126.1(V)

at 11:11:54 : V1 116.4(V), V2 96.6(V), V3 143.2(V)

E-4 Harmonics Improvement
(Separation of Circuits/Increasing Cable Size/Installation of Reactors)

1. Theory/Principle

(1) What generates harmonics?

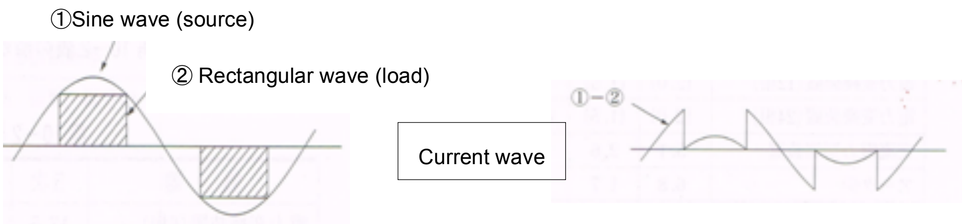
1) Non-Linear Circuit (analogue)

Ex. Transformer magnetizing current, Capacitor charging current

2) Switching Circuit (digital)

Ex. Inverter, Rectifier, Furnace & Heater power unit, Electronics equipment

Note: Some load doesn't require sine wave current. The balance current (①−②) contains harmonics and flows out to power system.



(1) What are the effects of harmonics?

・All equipment are designed to operate under rated frequency (50Hz).

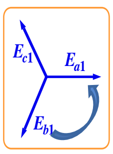
・Harmonics (150Hz, 250Hz, 350Hz---) cause equipment unnecessary and unstable movement, vibration, noise and excess heat which may damage equipment and/or cause malfunction of control system.

・Capacitors are weak for harmonics.

$Zc = 1/\omega C = 1/2\pi fC$, $Ic = V/Zc = 2\pi fCV$, f -> large, Ic -> large : **damaged !**

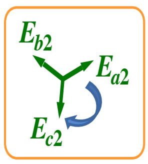
Zc : Impedance of capacitor, C : Capacitance, f : frequency, Ic : Capacitor current

・Vector rotation of harmonics



Positive phase rotation

n = 1, 7, 13, 19, ---



Negative phase rotation

n =5, 11, 17, ---

Cause worst effect !

Cause opposite rotation power to rotary equipment !

Outline

(1) High harmonics level on 2 Spot Welding Machines (20kVA & 15kVA) on Base Line Audit in November 2016

<u>Solutions</u>

1) Common cable for 2 machines were separated.

2) Size of cables was increased.

<u>Results</u>

20kVA Welding Machine : November 2015

	V	A	PF (%)	kW	THD L1(%V)
MAX	409.6	103.5	60.9	22.1	18.9
MIN	394.3	0.0	0.0	0.0	6.7
AVERAGE	404.0			1.5	8.1

20kVA Welding Machine : August 2016

	Volt	A/2	PF%	kW/2	THD%VL2
Max	387.3	73.6	101.4	15.5	6.3
Min	374.3	0.0	0.0	0.0	3.6
Average	381.7	12.2	16.8	2.3	4.6

15kVA Welding Machine : November 2015

	V	A	PF (%)	kW	THD L1(%V)
MAX	409.1	77.7	105.3	16.7	10.1
MIN	396.9	0.0	0.0	0.0	6.9
AVERAGE	403.3				8.4

15kVA Welding Machine : April 2016

	V	A	PF (%)	kW	THD L1(%V)
MAX	393.0	98.1	70.6	26.2	7.4
MIN	375.0	0.0	0.0	0.0	4.8
AVERAGE	385.4	11.8	13.7	2.2	5.9

(2) High harmonics level on Hydraulic Press Unit (total 70kW) on Base Line Audit in November 2016

<u>Solution</u>

1) Installation of reactors on primary side of hydraulic pump motors

<u>Results</u>

Hydraulic Press Unit (Total 70kW)

November 2015

	V	A	PF (%)	kW	THD L1(%V)
MAX	395.0	153.1	94.5	93.4	6.8
MIN	371.7	34.7	70.9	16.7	5.0
AVERAGE	386.0	69.1	83.4	39.9	5.9

April 2016

	V	A	PF (%)	kW	THD L1(%V)
MAX	375.8	168.0	91.9	94.1	5.7
MIN	353.3	0.0	0.0	0.0	3.3
AVERAGE	368.3	64.2	81.7	34.6	4.0

Hydraulic Pump (15kW)

November 2015

	V	A	PF (%)	kW	THD L1(%V)
MAX	395.0	41.3	136.3	26.3	9.8
MIN	372.9	6.0	61.6	3.6	5.1
AVERAGE	388.4	16.6	80.6	8.8	6.3

April 2016

	V	A	PF (%)	kW	THD L2(%V)
MAX	375.7	44.5	92.9	25.1	5.7
MIN	354.2	4.9	73.6	2.4	3.7
AVERAGE	368.8	13.5	89.5	7.8	4.4

E-5 Harmonics Improvement
（Application of 12 Pulse Rectifier/Active Filter/Series Reactor for Capacitors）

1. Theory/Principle

   Same as Harmonics Improvement Electrical (E-4)

2. Outline

   High harmonics level was measured on all electrical system in the factory because of many rectifiers for electroplating and power factor improvement capacitors without series reactors. In the factory several equipment damages/malfunction of control system (power factor controller, capacitors, CT, generator, etc.) occurred before.

2-1 High harmonics level on Generator (195kVA) supplying power to 6 sets of 6 pulse Electroplating Rectifiers (1 X 10,000A, 2 x 8,000A, 3 x 2,000A) on 2nd Audit in April 2016.

	V	A	PF (%)	kW	THD L1 (%V)
MAX	364.8	145.0	42.8	37.9	18.4
MIN	362.9	120.3	41.4	31.6	17.6
AVERAGE	364.0	130.8	41.7	34.4	17.8

Improvement proposals (under planning)

1) Improvement proposal-1

   Replacing 3 set of 6 pulse big rectifiers with 12 pulse rectifiers which generate less harmonics.

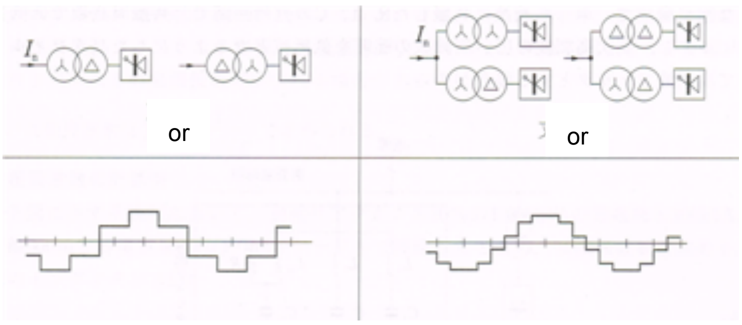
   Application of 12 pulse rectifiers

   → AC side wave distortion becomes smaller (reducing harmonics)

   (THD (%V) by 12 pulse rectifier is nearly half of THD (%V) by 6 pulse rectifier.)

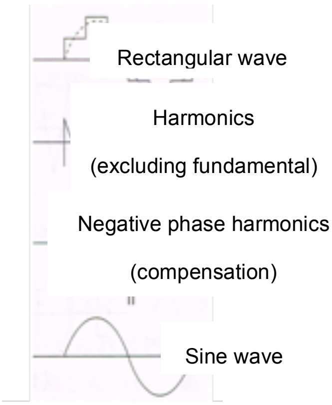
6 pulse rectifier 12 pulse rectifier

AC input current



2) Improvement proposal-2

Installation of Active filter which eliminates/reduces harmonics level by providing negative phase harmonics (compensation).



Operating principle

2-2 High harmonics level on power receiving point due to power factor improvement capacitors without series reactors on 2nd Audit in April 2016.

The harmonics seem to affect power factor controller and capacitors.

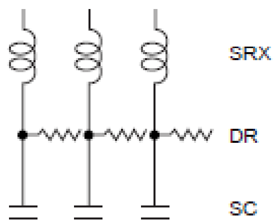
	V	A	PF (%)	Pfo(%)	kW	THD L2(%V)
MAX	421.2	424.0	121.9	98.8	212.3	11.0
MIN	382.8	243.8	58.6	58.6	145.4	3.5
AVERAGE	408.3	292.2	110.5	83.4	171.7	9.2

1) Improvement proposals (under planning)

Series Reactor should be installed for capacitors. 6% Series Reactor for Power Factor Improvement Capacitor is effective for 5th or higher harmonics.

In Pakistan Static Capacitors (SC) are well installed near power receiving point for avoiding fine/penalty from power company. But Series Reactors (SRX) are not installed in almost factories. Static Capacitors (SC) and its control system are suffered from harmonics.

Series Reactors (SRX) should be installed for protection of capacitors and preventing harmonics to flow out from capacitors.



E-6 Harmonics Improvement
(Operational Limitation (Reducing Harmonics Generation) and Installation of Harmonics Filters on CNC Control System)

1. Theory/Principle

   Same as Harmonics Improvement Electrical (E-4)

2. Outline

   High harmonics level was measured on all electrical system in the factory because of induction furnace power unit. The power unit supplies high frequency power to 300kg crucible or 500kg crucible. In the factory CNC control system and AVRs for CNC got damaged several times.

2-1 High harmonics level

(1) Induction furnace power unit and CNC machines before improvement.

a)500kg crucible operation, Oct. 2016

	Volt	Amp	PF%	kW	Thd% V L3
Max	367.9	570.6	95.3	332.9	10.3
Min	352.5	259.5	94.5	156.3	6.9
Average	359.7	404.8	95.0	239.1	8.3

b) 300kg crucible operation, Oct. 2016

	Volt	Amp	PF%	kW	Thd% V L3
Max	384.2	352.2	95.1	213.7	8.8
Min	365.7	0.0	0.0	0.0	1.7
Average	372.2	265.7	92.6	161.6	6.8

c) CNC-2 Transformer input at 500kg operation

	V	A	PF	KW	Thd% V L2
MAX	386.6	42.6	196.2	2.7	23.9
MIN	341.6	1.1	0.0	-5.7	8.2
AVERAGE	355.7	6.0	173.6	0.5	11.6

d) CNC-3 input/AVR output at 500kg operation

	V	A	PF	KW	Thd% VL2
MAX	416.6	10.9	101.4	5.6	33.6
MIN	371.0	4.5	45.2	1.4	8.7
AVERAGE	389.2	6.2	62.0	2.7	20.3

(2) Tentative improvement proposal

Max output of the induction furnace should be limited to 210kW, suitable for 300kg crucible operation in order to reduce harmonics generation.

c) CNC-2 Transformer input at 300kg operation

	V	A	PF	KW	Thd% V L1
MAX	405.9	55.6	111.1	34.6	9.8
MIN	385.3	3.8	45.6	-12.1	7.5
AVERAGE	398.3	10.7	72.4	5.0	8.3

d) CNC-3 input at 300kg operation (No AVR)

	Volt	Amp	PF%	kW	Thd% V L1
Max	404.5	35.6	191.9	21.8	9.6
Min	390.3	6.2	38.5	-3.6	4.6
Average	398.9	7.7	51.7	2.7	8.8

Note: AVR for CNC-3 was burnt during the Audit.

(3) Improvement proposal

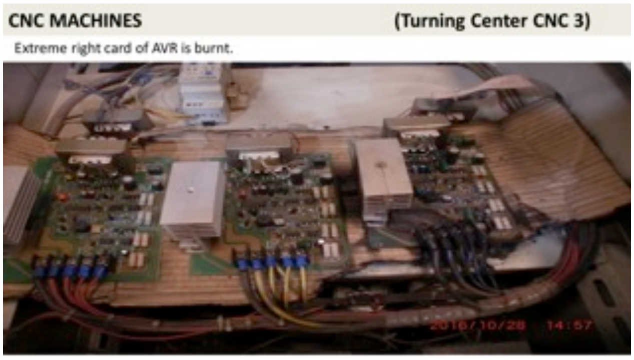
a) Harmonics filters should be installed on all CNC machines. To consult CNC manufacturers.

b) AVRs should be removed since AVRs themselves generate harmonics. After increasing power receiving voltage by adjusting receiving transformer taps, whole factory voltage was improved. → Continuous monitoring required.

c) For operation of 500kg crucible to recover productivity, either of following measures should be taken for not increasing harmonics.

- Replacing existing Induction power unit of 6 pulse rectifier with Induction power unit of 12 pulse rectifier. --- High cost.
- Installation of Active filter --- High cost and high technology required.
- Installation of AC filter --- Medium cost and detail survey and engineering calculation required.

(Reference) Burnt AVR Circuit Board



E-7 Application of Inverter for Pump

1. Theory/Principle

How to save energy of motors which usually consume most energy in factories.

--- Application of Inverters for motors is most effective !

(Inverter varies frequency then motor/pump/fan speed varies.)

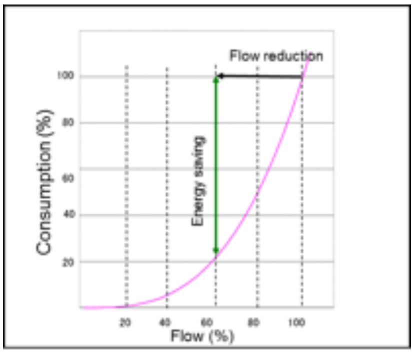
Water/air volume (Q : m^3/s) ∝ f (Hz) (∝ : in proportion to)

Water/air pressure (H: N/m^2) ∝ f^2

Motor Consumption (P : kWh) ∝ f^3

Ex) f : 50 Hz → 40 Hz (80%)

Q → 0.8 Q, P → 0.8 x 0.8 x 0.8 P = 0.51 P (HALF !)



Energy saving Performance (Cubic function curve)

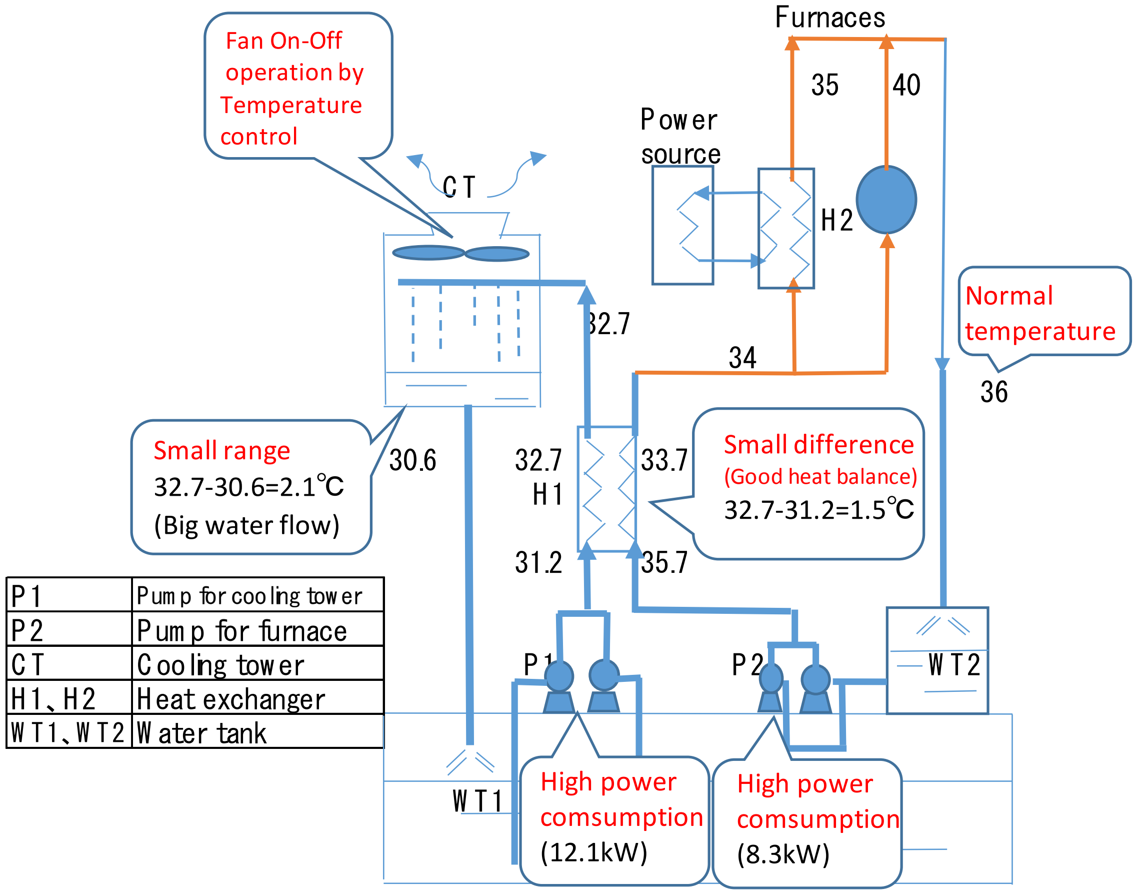
2. Outline

Case-1

Temperature difference of 1.5℃ (=32.7-31.2) between inlet and outlet of the cooling tower (or Heat exchanger H1) was small because of excess water flow. Pump P1 consumption was 12.1kW.

Case-2

Temperature difference of 2.0℃ (=36-34) between inlet and outlet of Heat Exchanger H2 was small because of excess water flow. Pump P2 consumption was 8.3kW.



P1	Pump for cooling tower
P2	Pump for furnace
CT	Cooling tower
H1、H2	Heat exchanger
WT1、WT2	Water tank

3. Improvement proposal for energy efficiency (ongoing)

Case-1

(1) Reducing the water flow (Q1') and increasing the temperature difference to 2.0℃ was recommended.

Q1' x 2.0 = Q1 x 1.5 → Q1' = 1.5/2.0 x Q1 = 0.75 x Q1

Q1': Water flow volume at temperature difference of 2.0℃ for cooling tower circulation

(2) Application of inverter was suitable for above purpose.

Consumption of the pump (P) after reducing flow volume to 75%.

P1 = 12.1 x 0.75 x 0.75 x 0.75 = 5.1 kW (42%)

(3) Energy saving calculation

Operation conditions: 16hrs/day, 25days/month, 12months/year, 17Rs/kwh

Energy saving W1(kWh) = (12.1 – 5.1) kW x 16hrs x 25days x 12months = 33,600kWh/year

Energy saving C1(Rs) = W1 x 17Rs/kWh = 571,200Rs/year

(4) Investment and Payback time

1) Example of inverter price and maker

Model: N300-110HF / N700-110HF   for 11kW (15HP)

Price I1(Rs): 160,000Rs/unit

HYUNDAI INDUSTRIES Co, Ltd   Made in Korea

2) Payback time

T = 2 x I1/C1 = 0.56years (6.7months)

For 2 sets of inverters (normal, standby)

Case-2

(1) Reducing the water flow (Q2') and increasing the temperature difference to 2.5℃ was recommended.

Q2' x 2.5 = Q2 x 2.0 → Q2' = 2.0/2.5 x Q2 = 0.8 x Q2

Q2': Water flow volume at temperature difference of 2.5℃ for cooling tower circulation

(2) Application of inverter was suitable for above purpose.

Consumption of the pump (P) after reducing flow volume to 75%.

P2 = 8.3 x 0.8 x 0.8 x 0.8 = 4.2 kW (51%)

(3) Energy saving calculation

Operation conditions: 16hrs/day, 25days/month, 12months/year, 17Rs/kwh

Energy saving W2(kWh) = (8.3 – 4.2) kW x 16hrs x 25days x 12months = 19,680kWh/year

Energy saving C2(Rs) = W2 x 17Rs/kWh = 334,560Rs/year

(4) Investment and Payback time

1) Example of inverter price and maker

Model: N300-110HF / N700-110HF   for 11kW (15HP)

Price I2(Rs): 160,000Rs/unit

HYUNDAI INDUSTRIES Co, Ltd   Made in Korea

2) Payback time

T = 2 x I2/C2 = 0.96years (11.5months)

For 2 sets of inverters (normal, standby)

E-8 Application of Inverter for Hydraulic pump

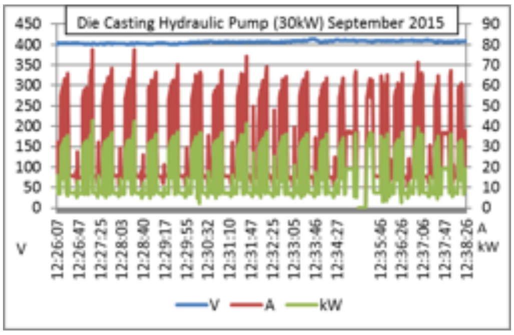
1. Theory/Principle

   Same as Application of Inverter for Pump Electrical (E-7)

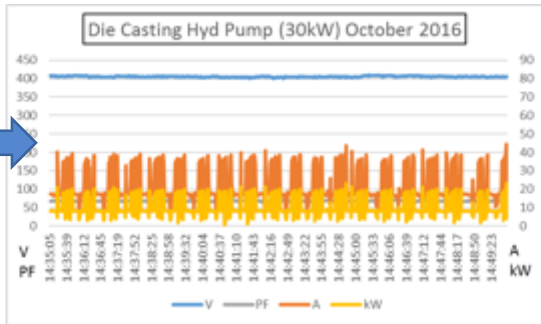
2. Outline

   Hydraulic pump (30kW) of Die Casting Machine was running on overload situation.

   The pump speed was controlled by pre-installed inverter at 32Hz.



Inverter : 32Hz



Inverter : 28Hz

	V	A	PF (%)	kW	THDV L3(%V)
MAX	414.0	77.5	82.5	42.6	6.1
MIN	399.6	0.0	0.0	0.0	5.2
AVERAGE	406.1	29.3	69.0	15.1	5.7

	V	A	PF (%)	kW	Thd%V L1
MAX	410.1	44.6	77.9	23.0	7.7
MIN	400.5	0.0	0.0	0.0	5.7
AVE	405.2	20.3	68.5	10.0	6.6

3. Improvement proposal

   Inverter frequency should be reduced to 29.5Hz for reducing overload situation and saving energy.

   Reduced motor input: Po = 42.6 x $(29.5/32)^3$ = 33.3kW (=30kW output, Efficiency: 0.9)

4. Results

(1) Factory reduced inverter frequency step by step (32Hz → 30Hz → 29.5Hz → 28Hz) confirming no effect to product quality and efficiency.

(2) As a result, without investment factory achieved energy saving:

55,700kWh/year, 668,400Rs/year

E-9 Application of Inverter for fan/blower

1. Theory/Principle

   Same as Application of Inverter for Pump Electrical (E-7)

2. Outline

   3 exhaust fans (11kW) average consumption (input) is as follows.

   Exhaust fan 1: 8.3kW, Exhaust fan 2 : 6.3kW, Exhaust fan 3 : 5.1kW,

   Air leakage occurs from holes and space on ducts.

3. Improvement proposal (under planning)

(1) Air leakage can be reduced by repairing duct hole and space, then air flow can be also reduced, at least 10%. → Application of inverters were recommended for reducing air flow by 10%.

(2) Consumption of the blowers after reducing air volume to 90%.

$P1 = 8.3kW \times (0.9)^3 \fallingdotseq 6.1kW$

$P2 = 6.3kW \times (0.9)^3 \fallingdotseq 4.6kW$

$P3 = 5.1kW \times (0.9)^3 \fallingdotseq 3.7kW$

(3) Energy saving calculation

Operation conditions: 24hrs/day, 25days/month, 12months/year (300days/year), 20Rs/kwh

10% reduction of exhaust air volume

Energy saving W1(kWh) = (8.3 – 6.1) kW x 24hrs x 300days/year = 15,840kWh/year

Energy saving C1(Rs) = W1 x 20Rs/kWh = 316,800Rs/kWh

Energy saving W2(kWh) = (6.3 – 4.6) kW x 24hrs x 300days/year = 12,240kWh/year

Energy saving C2(Rs) = W2 x 20Rs/kWh = 244,800Rs/year

Energy saving W3(kWh) = (5.1 – 3.7) kW x 24hrs x 300days/year = 10,080kWh/year

Energy saving C3(Rs) = W2 x 20Rs/kWh = 201,600Rs/year

Total Energy saving W(kWh) = W1 + W2 + W3 = 38,160kWh/year

Total Energy saving C(Rs) = C1 + C2 + C3 = 763,200Rs/year

(4) Investment and Payback time

1) Example of inverter price and maker

Model: N300-110HF / N700-110HF for 11kW (15HP)

Price I(Rs): 160,000Rs/unit

HYUNDAI INDUSTRIES Co, Ltd Made in Korea

2) Payback time

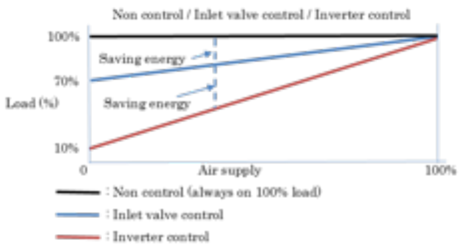
T = 3 x I/C = 0.63years = 7.5months

Note: In the factory this improvement proposal will be planned after reducing high harmonics level because adding inverters will increase harmonics level furthermore.

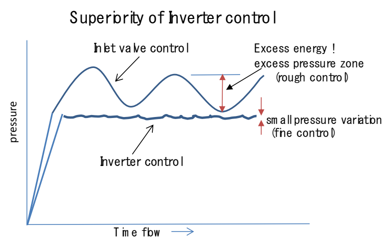
E-10 Application of Inverter for Compressor

1. Theory/Principle

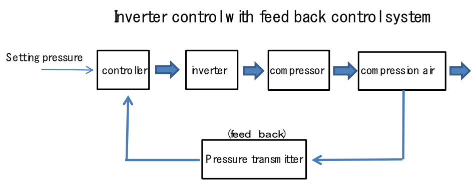
   As compressor control Load-Unload control system has been commonly applied since On-Off control system requires frequent restarting of the compressor, which results in damaging equipment and shortening equipment life. But Load-Unload control system is not so preferable from energy saving point of view since on the control system compressor consumes nearly 70% energy even during non-air-supply period. Therefore, inverter controlled compressor system has been introduced in the industry.



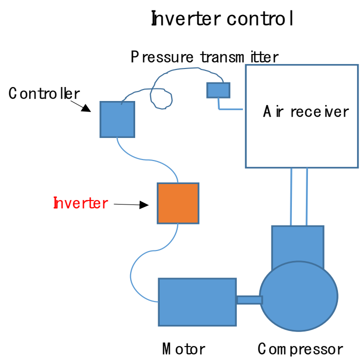
Energy Saving Performance



Control Characteristics



Inverter control system



Inverter control outline

2. Outline

   Existing screw compressor (rated 55kW) was getting old and the screws got worn, therefore, the maximum output lowered to around 45kW.

3. Improvement proposal

   The old compressor (55kW) should be replaced with new compressor (55kW) with built-in inverter. The old compressor should be used as standby compressor.

4. Results

(1) Energy saving amount

Good energy saving is achieved as follows. (including air leakage reduction)

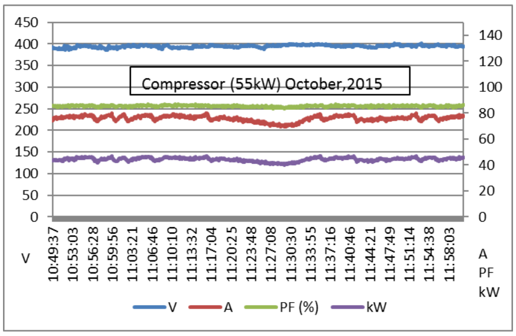
- Consumption reduction: P = (44.3 + 37.4) – 48.2 = 33.5kW
- Consumption reduction: W = P x 10hrs x 24d x12m = 96,480kWh/year
- Electricity cost reduction: C = W x 18Rs/kWh = 1,736,640Rs/year

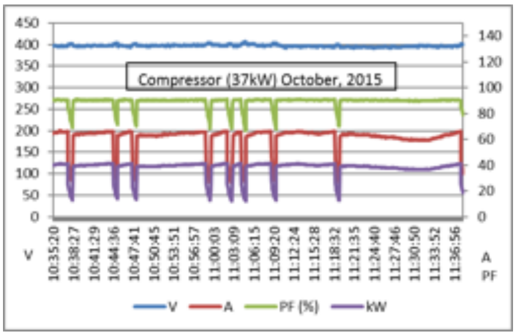
(2) Investment and Payback time

Investment on new compressor with built in inverter: I = 2,200,000Rs

Payback time: T = I/C = 1.27years

Before improvement (2 compressors run simultaneously.)





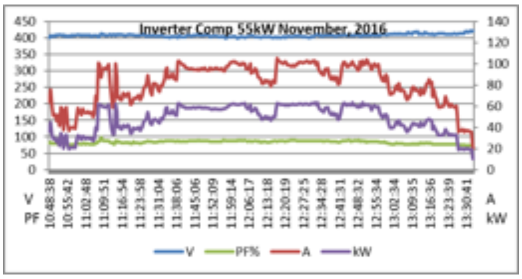
Sampling :5sec

	V	A	PF (%)	kW	Thd%V L2
MAX	401.0	80.0	86.9	46.9	7.5
MIN	385.1	69.4	83.6	40.1	3.5
AVERAGE	394.7	75.9	85.4	44.3	4.4

Sampling :5sec

	V	A	PF (%)	kW	Thd%V L1
MAX	407.0	66.7	91.0	41.2	4.8
MIN	391.8	26.2	66.6	12.3	3.4
AVERAGE	396.8	60.8	89.0	37.4	3.8

After improvement (One inverter compressor is enough for normal factory operation.)



Sampling :30sec

	Volt	Amp	PF%	kW	Thd%V L3
Max	420.7	105.3	98.0	63.3	7.8
Min	398.1	20.0	70.5	10.3	4.2
Average	407.3	81.1	83.5	48.2	6.0

Note: Inverter compressor motor consumption/output varies according to air requirement in order to keep air pressure to setting value.

E-11 Cable Size Improvement

1. Theory/Principle

   In case cable size is not enough for current capacity, cables cause excess heat by cable resistance (I^2R), cable insulation is damaged and fire may occur in worst case.

   Correct cable size selection is important from both SAFETY and ENERGY SAVING points of view.

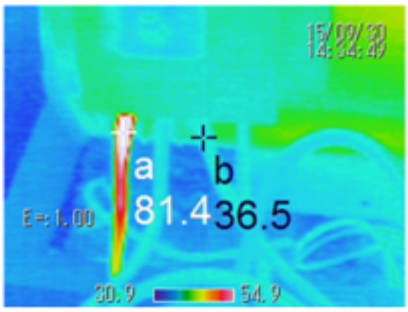
2. Outline

2-1 Case-1 Generator (250kVA) main cable (Base Line Audit in September 2015)

- A Phase main cable size is smaller than other phase cables and over heated. Measured temperature is 81.4℃ vs allowable temperature of 70℃ for PVC (Fast Cables Ltd.).

  ➡ To be replaced with bigger size cable or additional cable.

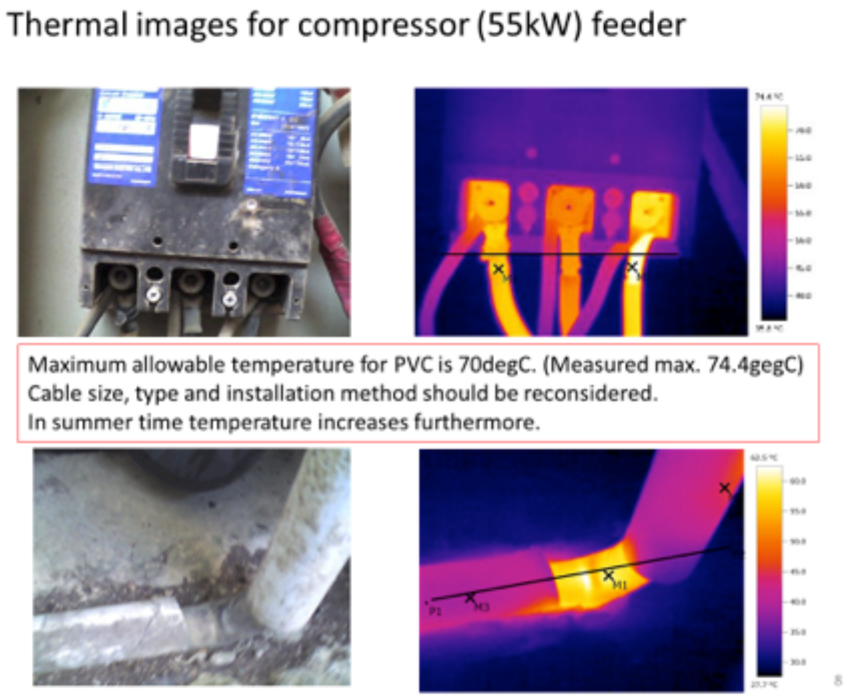
Inspection by Thermo-view



Results: A Phase main cable size was replaced with same size cable as other phase cables

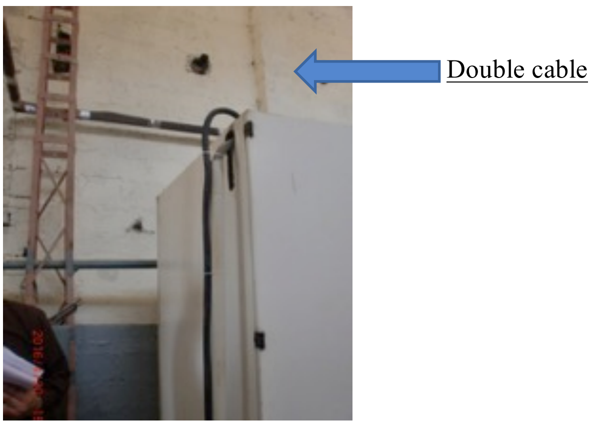
Temperature rise was confirmed to be lowered on 2nd Audit in March 2016.

2-2 Case-2 Compressor (55kW) cable (Base Line Audit in October 2015)



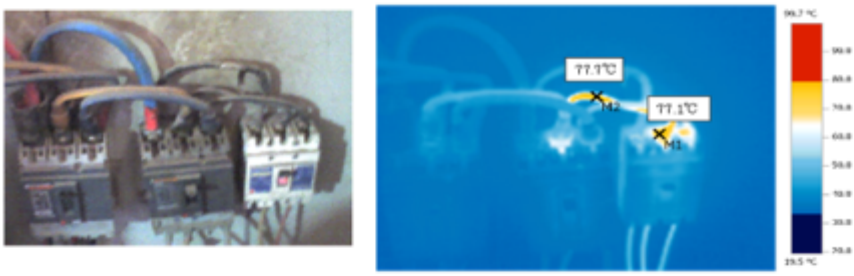
Results: Additional cable was installed for increasing cable size (double cable system).

Temperature rise was confirmed to be lowered on 2nd Audit in April 2016.



2-3 Case-3 Compressor (15kW) Cubicle wiring (Base Line Audit in November 2015)

Thermal images for compressor (15kW) feeder



Maximum allowable temperature for PVC cable is 70degC. (Fast Cables Ltd.)
(Measured max. 77.7gegC). Cable size should be increased.
In summer time temperature increases furthermore.

17

Results: The cubicle wiring was replaced with bigger size wiring.
Temperature rise was confirmed to be lowered on 2nd Audit in April 2016.

2-4 Case-4 External cable and Cubicle wiring (Base Line Audit in November 2015)

Thermal Image of Oven Control Panel

M1 : 63.7, M2 : 82.0, M3 : 73.8, M4 :46.5 (degC)

Maximum allowable temperature for PVC cable is 70degC. (Fast Cable Ltd.)
(Measured max. 82degC).
Cable size should be increased or heat resistant cover should be put on cable surface.
Investigation is required. In summer time temperature increases furthermore.

18

Results: Both external cable and cubicle internal wiring were replaced with bigger size cable and wiring. Temperature rise was confirmed to be lowered on 2nd Audit in April 2016.

E-12 Measurement of Specific Consumption of Product (Insulation Cover on Barrel Heater of Injection Molding Machine)

1. Theory/Principle

   Measuring specific consumption of product is important and effective for evaluation of energy efficiency. The first data of the consumption is benchmark of the product energy efficiency.

2. Outline

   Specific consumption of Product A (P1) of Injection Molding machine was measured on Base Line Audit in October 2015. On the audit improvement proposal of insulation cover on barrel heater was recommended. On the 2nd Audit in May 2016 specific consumption of Product A (P2) was measured in the same way. Before the audit insulation cover was put on the heater and preventative maintenance of hydraulic unit of the machine including oil replacement was carried out additionally. As a result specific consumption of Product A was significantly improved.

Injection Molding Machine (Total 62kW)

October 2015

	V	A	PF (%)	kW	THD L1 (%V)
MAX	395.5	62.3	112.7	36.6	6.7
MIN	371.5	32.4	96.8	21.1	5.0
AVERAGE	385.3	41.9	102.1	27.3	5.6

May 2016

	V	A	PF (%)	kW	THD L3 (%V)
MAX	398.7	47.9	100.0	25.4	6.9
	368.5	0.0	0.0	0.0	4.1
AVERAGE	385.3	33.0	59.3	12.4	5.5

Average energy reduction: 27.3 – 12.4 = 14.9kW

Calculation of specific consumption per Product A (P1 & P2)

Consumption of 10pcs of product A: Po1 = 10.70kWh/10pcs, Po2 = 7.0kWh/10pcs

Consumption of 1pcs of product A: P1 = 1.07kWh/pc, P2 = 0.70kWh/pc

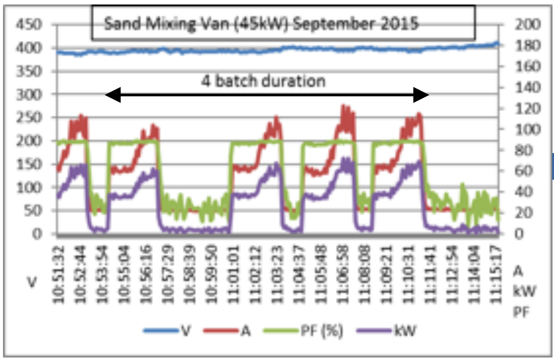
Energy consumption reduction ratio: a = P2/P1 x 100 = 65.4%

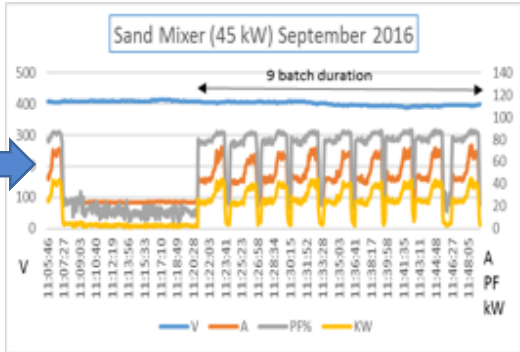
This evaluation method is effective for further improvement, other products even for other manufacturing process.

E-13 Rectifying Weighing System of Sand Plant

1. Outline

On Base Line Audit in September 2015 improper weighing of sand material and subsequently overloading of 45kW motor (input Max.72.5kW) were observed. Factory replaced the weighing system and sand mixer blades, then operation and energy efficiency improved.





	V	A	PF (%)	kW	ThdV L3 (%)
MAX	410.2	122.0	89.1	72.5	7.2
MIN	385.4	21.3	6.2	1.0	3.4
AVERAGE	395.3	52.8	60.0	27.2	5.5

	V	A	PF %	kW	Thd L1 (%V)
Max	409.7	74.8	88.5	45.0	5.9
Min	387.7	22.5	10.3	1.7	4.4
Avg	399.5	49.1	75.0	26.9	5.1

	Time	kWh	
Start	10:53:49	3556.87	
Stop	11:11:41	3565.932	
Total time	0:17:52	9.062	/4batches
Batch time	0:04:28	2.2655	/batch
	(268sec)		

	Time	kWh	
Start	11:20:53	6331.308	
Stop	11:49:16	6343.94	
Total time	0:28:23	12.6319	/9batches
Batch time	0:03:09	1.403544	/batch
	(189sec)		

Results:

1) Overloading of 45kW motor was solved (input Max. 72.5kW → 45.0kW).
2) Energy efficiency was improved (2.27kW/batch → 1.40kW/batch: 62%).
3) Energy saving amount: 17,000kWh/year → 289,000Rs/year (19,728batches/year)
4) Productivity was improved (Batch time: 268sec → 189sec).
5) Quality of product was improved.

M-1 Improvement of the cooling water system

This factory product die cast parts of car. The Specifications of the cooling water system for the production plant is as follow.

(1) High-frequency induction furnaces (→ furnace)

Number of plant: 2 units.

Power consumption of the furnace: 200kW

(2) Cooling tower: 60ton *1unit

(3) Cooling tower circulation pump: 12kW*2units. Furnace circulation pump: 12kW*2units

(4) Heat exchanger: Plate type*2units

1-1.The matters of the cooling water system

- Return temperature of the furnace cooling water line is high temperature.
- In the furnace circulating cooling water line, source line and furnace line are series connection (see Fig1).

  The water flow decreases with increase of piping resistance by the series connection and return temperature is too high.
- Water flow for cooling tower circulation is too much quantity.
- The cooling tower circulating pump and the furnace circulating pump are high power consumption due to big water flow.
- The cooling tower fan is continuous running in all working times.

  The cooling water system for the furnace is shown Fig1.

1.2 Improvement suggestion:

The problem 1: Return temperature of cooling water for the furnace is high.

⇨ To remodel piping for the furnace cooling line from series connection to parallel connection.

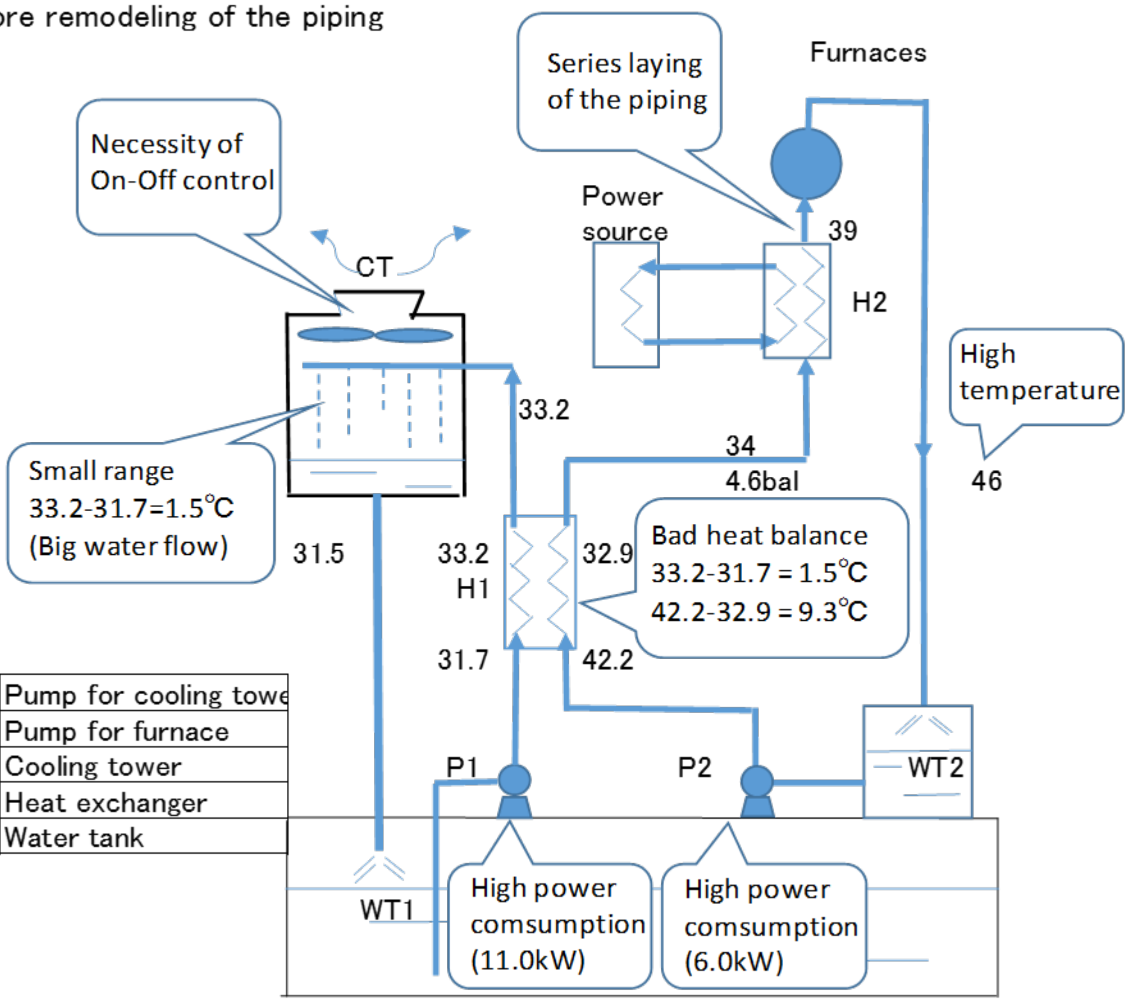
The problem 2: High consumption of the pumps

⇨ To install inverters for the cooling tower circulation pump and the furnace circulation pump.

The problem 3: Continuous running of the cooling tower fan in all working time.

⇨ To introduce ON/OFF control system by thermal sensor.

Fig1 Before remodeling of the piping



P1	Pump for cooling towe
P2	Pump for furnace
CT	Cooling tower
H1、H2	Heat exchanger
WT1、WT2	Water tank

1.3 The result of the improvement

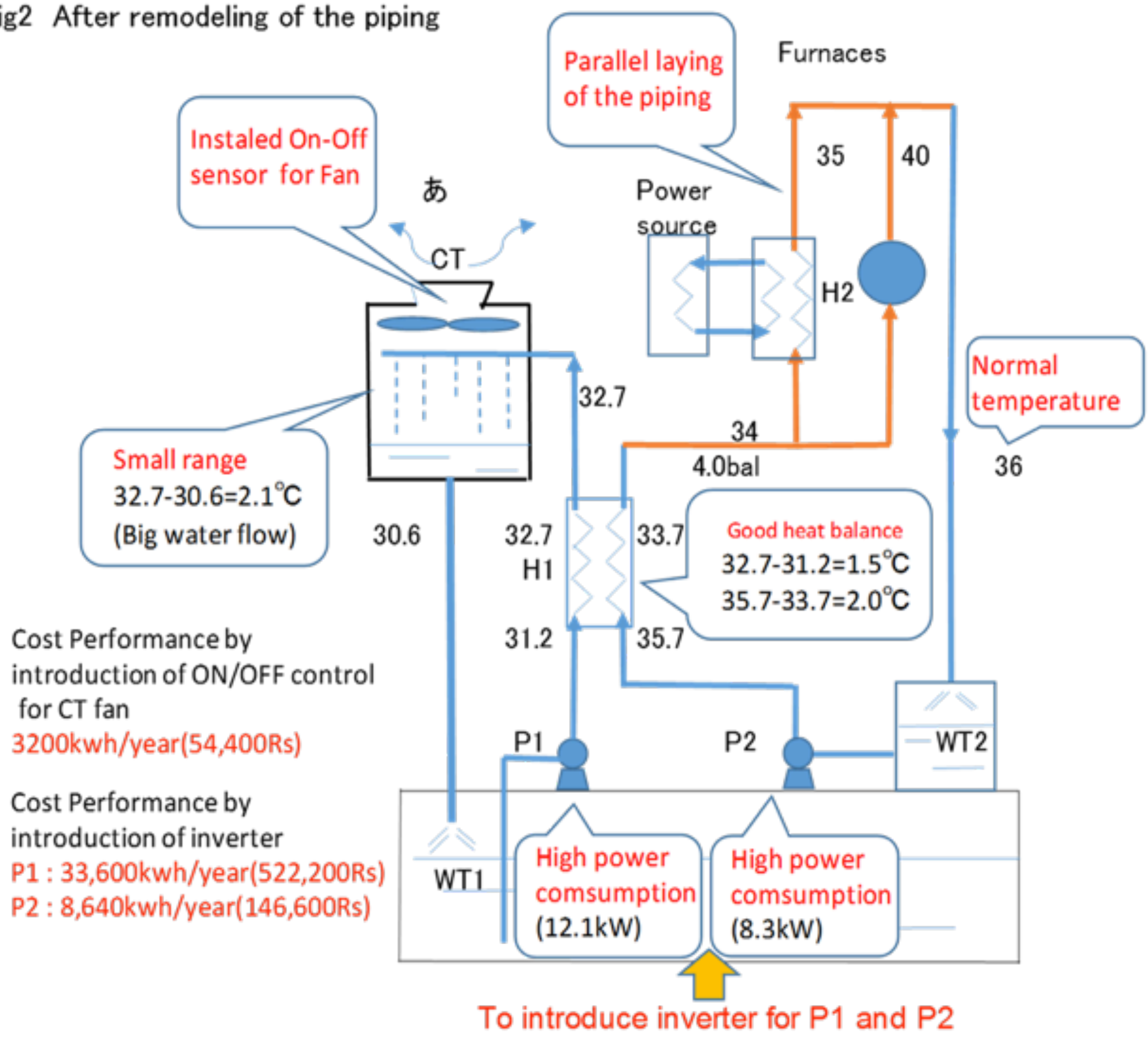
The problem 1: Return temperature of cooling water for the furnace is high. → After remodeled piping for the furnace cooling line from series connection to parallel connection, return temperature decreased 10℃from 46 ℃ to 36℃. (see Fig 2)

The problem 2: High consumption of the pumps. → The consumption of the furnace circulation pump increased more because water flow increased. (see Fig2)

The problem 3: Continuous running of the cooling tower fan in all working time. → Introduced ON / OFF control system by thermal sensor. The control temperature of cooling water is ON at 30℃、 OFF at 25℃.

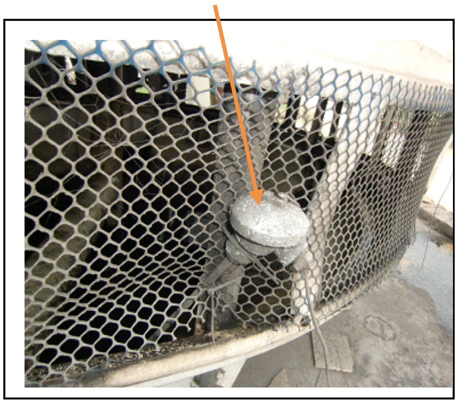
The energy saving is possible in the winter season by this control system.

Fig2 After remodeling of the piping



1.4 calculation for energy saving

Thermocouple



1.4.1 ON /OFF control of the cooling water fan

Condition:

(1) Fan ON at 30degC Fan OFF at 25degC

(2) Working time: 400hr / month

(3) Continuous operation season: 5months (May – Aug’)

(4) No need fan operation season : 3 months(Nov', Dec', Jan')

(5) 200hr/month operation : 4month(Mar‘, Apr', Sep', Oct')

(6) Power consumption of the fan : 1.6kW

(7) 1kwh = 17Rs

Calculation

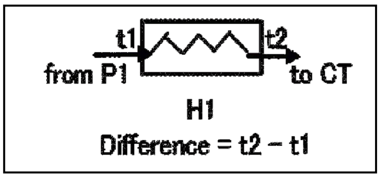
Energy saving / year = 1.6*(400*3 + 200*4) = 3,200kwh/year

Pay back = 3,200*17 = 54,400Rs

1.4.2 Energy saving by introduce of inverter:

1.4.2.1 The cooling tower circulation pump (P1)

Condition:



Difference temperature of heat exchanger (H1) before and after to introduce inverter is as follow.

P1: Cooling tower circulating pump

CT: Cooling tower

Before: 32.7(t2) – 31.2(t1) = 1.5degC

After: t2 – t1 = 2.0degC (setting)

When water flow quantity is Q1 (before) and Q2 (after), the following thermal balance is formed

Q1*1.5 = Q2*2.0 Q2/Q1 (flow ratio) = 1.5/2.0 = 0.75

Calculation of energy saving by introduce of inverter:

Power consumption after introduce: 11kW*0.75*0.75*0.75 ≒ 4.6kW

Energy saving / year = (11.0-4.6)*400hr/month*12month = 30,720kwh/year

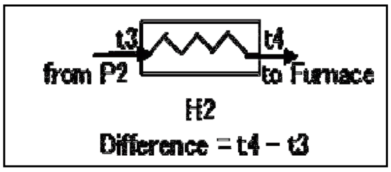
Pay back = 30,720kwh*17(Rs /kWh) ≒ Rs.522200 /year

1.4.2.2 The furnace cooling water circulation pump (P2)

As a result to be remodeled the piping from series to parallel, item (2) became good condition. In item (1), power consumption increased as follow.

Item	Before	After
(1) Power consumption	6kW	8.2kW
(2) Return temperature from the furnace	46℃	36℃

It is necessary to reduce the flow quantity because the water flow to be increased. The flow quantity can be reduced by temperature difference to increase as follow



Before: 36(t4) – 34(t3) = 2.0degC

After : t4 – t3 = 2.5degC (setting)

Water flow quantity: Before (Q3), After (Q4)

Q3*2.0 = Q4*2.5 Q4/Q3 (flow ratio) = 2.0/2.5 = 0.80

<u>Calculation of energy saving by introduce of inverter</u>:

Power consumption after introduce: 8.3kW*0.8*0.8*0.8 ≒ 4.2kW

Energy saving / year = (6.0 – 4.2)*400hr/month*12month = 8,640kwh/year

Pay back = 8,640kwh*17(Rs/kWh) ≒ Rs.146800 /year

M-2 Improvement of the lighting system (1)

This factory product die cast parts of car by 24hr production of 2 sift system. Production areas has many energy saving type lamps (85W*80, 24W*12) and all the lightings are switch on in all working times (24hr).

This factory had some maters for the lighting.

(1) Illumination on the working tables are too dark.

(2) All lamps are switch on in all day times.

(3) The Lighting for the CNC machine room has big power consumption. (85W*12units,24W*12units)

2-1. Improvement for the lighting:

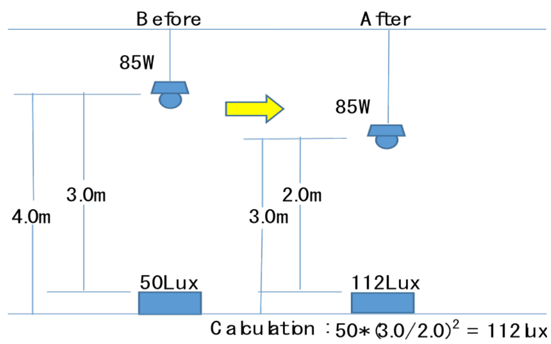
The problem. 1: Illumination on the working tables ware too dark(50lx) because lighting position too high (3m) from the working tables → To lower Lighting position from3m to 2m.

The problem. 2: All lamps were switch on in all day times → To install naturel daylights (sky lights) on the roof.

The problem. 3: The Lighting system for the CNC machine room had big power consumption → To replace the lighting from energy saver type to LED.

2-2. Improvement for the problem1

Illumination on the working tables increased to 2times (more than 100lx) by to make lower the lighting .



Measurement	Point1	Point2	Point3
Before	45 lx	60 lx	50 lx
After	95 lx	124 lx	111 lx

2-3. Improvement for the problem2

21 sheets of clear glass fiber naturel daylights (sky lights) was installed on the roof. In the result, All lamps (85W*68units) without CNC machine shop ware not necessary in all day times

Naturel daylights

Effect of the improvement

Effect1: To lower the lighting position. → Lighting environment is greatly improved in the night work.

Effect2: To install the naturel daylight on the roof. → The day light has big energy saving effect.

Energy saving: <u>17,555kwh/year Rs.263330/year (15Rs/kwh)</u>

Both effects of the energy saving and the environment improvement were achieved.

2-4. Improvement for the problem3

Energy saving type lamps (85W*12units + 24W*12units) ware replaced with LED type lamps (Tube type 18W*7units).

Effect of the improvement

To replace from energy saver type lamps to LED tube lights → Power consumption decreased 90%.

Energy saving /year: 6,030 kWh (90,450Rs)

Calculation of energy saving by the improvement									
Improvement		Replace to LED				Install naturel daylight			
Lighting time		8:00-18:00 (10hr)		18:00-01:00 (7hr)		8:00-18:00 (10hr)		18:00-01:00 (7hr)	
Before	Cosumption/unit	24W	85W	24W	85W	24W	85W	24W	85W
	Amount of unit	12	12	12	12	3	68	3	68
	Amount of consumption	288W	1020W	288W	1020W	72W	5780W	72W	5780W
	Consumption/day (kWh)	2.88	10.2	2.02	7.14	0.72	57.8	0.5	40.46
	Consumption/300days (kWh)	864	3,060	606	2,142	216	17,340	150	12,138
	15Rs/kWh*Consump'/300days	12,960	45,900	9,090	32,130	3,240	260,100	2,,250	182,070
	Amount	58,860Rs		41,220Rs		263,330Rs		184,320Rs	
	Amount(Rs and kWh) / shop	100,080Rs (6,672kWh)				447,650Rs (29,844kWh)			
After	Cosumption/unit	18W (LED)				0	0	24W	85W
	Amount of unit	7				0	0	3	68
	Amount of consumption	126W				0	0	72W	5,780W
	Consumption/day (kWh)	1.26		0.88		0	0	0.5	40.46
	Consumption/300days (kWh)	378		264		0	0	150	12,138
	15Rs/kWh*Consump'/300days	5,670Rs		3,960Rs		0	0	2,250Rs	182,070Rs
	Amount(Rs and kW) / shop	9,630Rs (642kWh)				184,320Rs (12,288kWh)			
Energy saving / shop /year		100,080-9,630 = 90,450Rs (6,030kWh)				447650-184320 = 263,330Rs (17,555kWh)			
[illegible]		[illegible]							

M-3 Improvement of lighting system (2)

3.1 Effect of the naturel day light cleaning

This factory product die cast parts of car by 24hr production of 2 sift system. Working times by 1 sift are 10hr/day, 300day/year.

Shops of the factory have naturel day lights. But lamps(Energy saver type 85W*16units) in these shops switch on in all day times because the naturel day lights ware dirty and working areas dark in the shops.

After cleaning naturel daylights, Illuminance in the shops increased and these shops did not need switch on lamps in all day times.

Illuminance of **before cleaning: 163 lx** (average) Illuminance of **after cleaning: 1250 lx** (average)

Before

After

3-2. Calculation for energy saving

Working times: 10hr/day (day time) 300days/year

Power consumption of the lamps: 85W*16 = 1360W

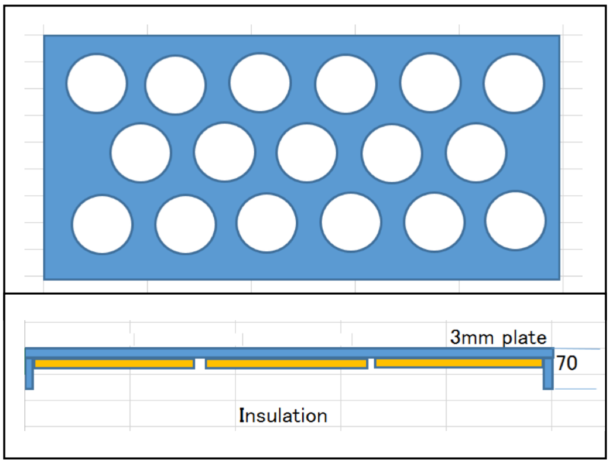
Energy saving /year = 1.36*10*300 = 4,080kwh

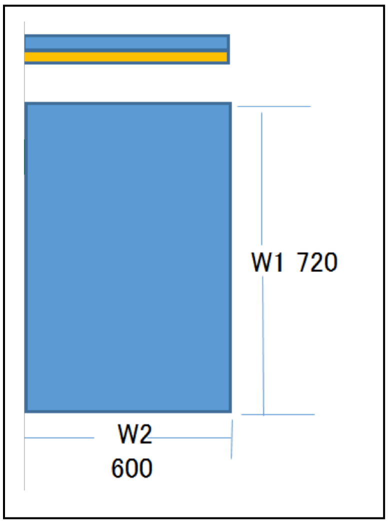
Energy saving / year: Rs.69360/year (17Rs/kwh)

M-4 Improvement of the heat loss from bonding oven of filters

This factory has hot plate type oven for bonding of filter by naturel gas burners. The bonding time is 8min per batch. However, the oven has high heat loss from surface of the hot plate. Therefore, the insulated filter holder to be made as follow. And put the cover on the no using holes.

After this improvement heat up time at start reduce from 30min to 20min and bonding time reduce from 8min to 7min.





Calculation for energy saving

Condition: Naturel gas consumption: 3MMBtu / day (Continue burning)

Consumption/hr: 0.3MMBtu working: 10h/day 288day / year Gas unit price: 600Rs / MMBtu

Reduce of startup time: 10min

Calculation (Saving of gas consumption)

(1). At start up heating: 10/60*0.3*288 = 14.4MMBtu (Rs.8640)

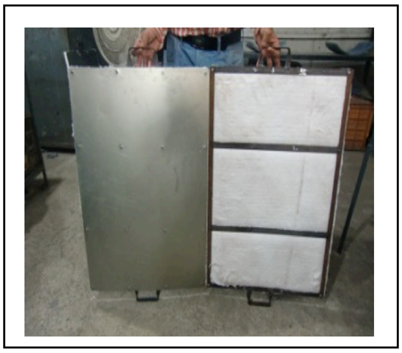
(2). Time shorten for production: 8-7/8*3btu*288= 108MMBtu (Rs.73,440)

Total saving / year = 122.4MMBtu (Rs.73,440)

Without holder

With holder

Cover for no use holes



M-5 Suggestion of induction furnace cover

This factory has 2 induction furnaces (250kW*1, 350kW*1) and Product system with 15hour / day, 300 day / year.

The operation time of the furnaces by 1 batch is 1 hour. But this factory does not has protect for from the radiant heat loss from the dissolution iron of 1400degC. Even other factories are same as this factory.

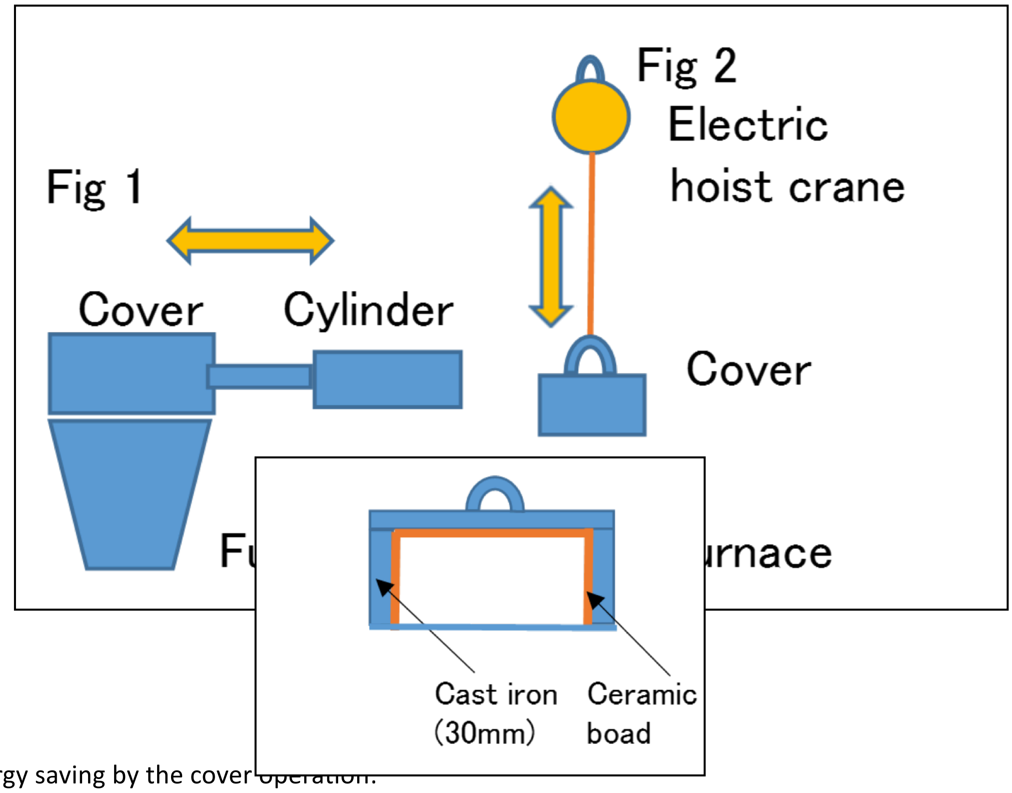
The protect of heat loss by the cover, is effective for time shortening by 1 batch.

In japan, when product die cast iron, induction furnace cover is used usually to reduce heat loss.

5.1. The timing which the cover is able to set on the furnace

5-2. Improvement of induction furnace

In japan, when induction furnaces are operated the cover is opened or closed by cylinder (see Fig 1). But many factories in Pakistan has not enough space for this operation. Therefore, recommend the operation by electric hoist crane as Fig 2.



5.3 Energy saving by the cover operation.

<u>The protect of heat loss by the cover is effective for time shortening by 1 batch. If can reduce 6 min by 1 batch, power consumption decreases 10%!</u>

- **Calculation**

<Condition> Power of the furnace: 200kW (average)

Time shortening: 3min 1 batch: 1 hour

Working: 10 batches/day   300days/year

Energy saving = 200*3/60*10*300 = 30,000kwh/year

= 510,000Rs/year (17Rs/kwh)

- **The method of time shortening**

1) To close the cover at waiting time.

   This time has 1/3 or more by 1 batch. (see 4.1)

2) If in operating, to close the cover diligently

3) To training the operators to be able to close the cover 1/2 or more by 1 batch.

M-6 Suggestion of fuel source changeover for power generator diesel engine.

6-1. Back ground of the suggestion

- This suggestion is something to change over from HSDO (High speed diesel oil) used for a generator to cheaper LDO (light diesel oil).
- LDO is made by to blend a little furnace oil into HSDO. The nature as the fuel is almost similar essentially in HSDO and LDO.
- The unit price of HSDO is around 100 Rs/L, and LDO is 70 Rs/L as same. Difference of both price is 30Rs. Therefore, change over from HSDO to LDO is effective for cost down of fuel oil price.
- There are a lot of cases with LDO for a generator of more than 200 kW of output in Japan.

6-2. Basic knowledge of the power generation in factories

(1) Indicate of the output

Generator: kVA Engine: kW

(2) Scale of the generators installed in factories in Pakistan: 100kVA – 650kVA

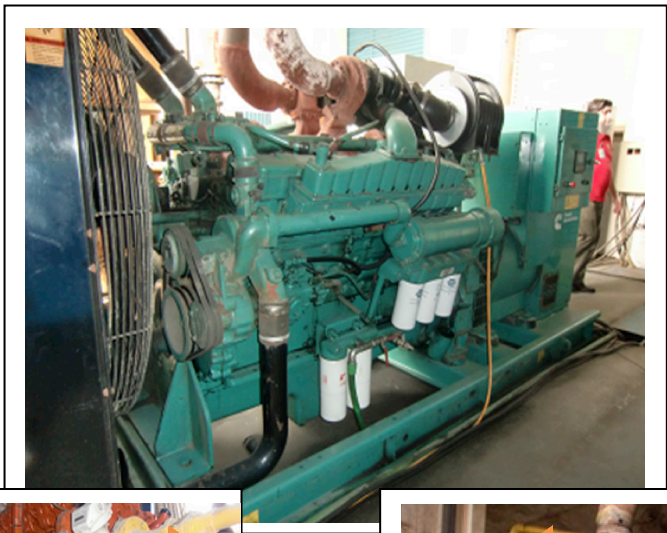
Type of engines and kind of fuels are as follow.

1) Diesel engine (Target of this suggestion) Fuel: High speed diesel oil (HSDO)

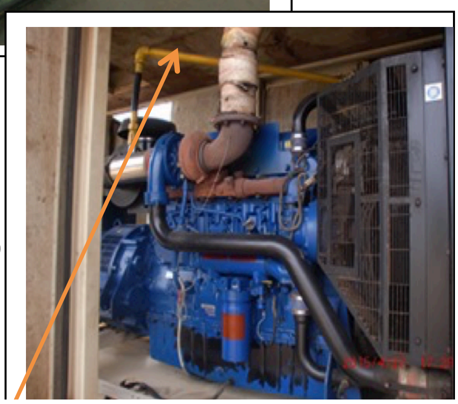
2) Gas engine Fuel: Naturel gas

3) Hybrid type engine Fuel: Blending of HSDO and naturel gas

Diesel engine



Gas engine



Naturel gas piping

6-3. Issues to use LDO

- The important specification of LDO

1) kinetic viscosity: Less than 20sec at 50degC (more than 2.7sec)

If too higher more than 20sec need heating.

2) Carbon reside: Less than 4% (HSDO: Less than 0.2%)

If too higher more than 4% it makes clogging the fuel filter.

3) Sulfur: Less than: 2% (HSDO = Less than 1%)

If too higher more than 2% makes metal corrode and makes air environment be aggravated.

4) Specific gravity: 0.85 (= HSDO)

Nasty oil has a high gravity. (Furnace oil: 0.92)

5) Cetane index: more than 45 (= HSDO)

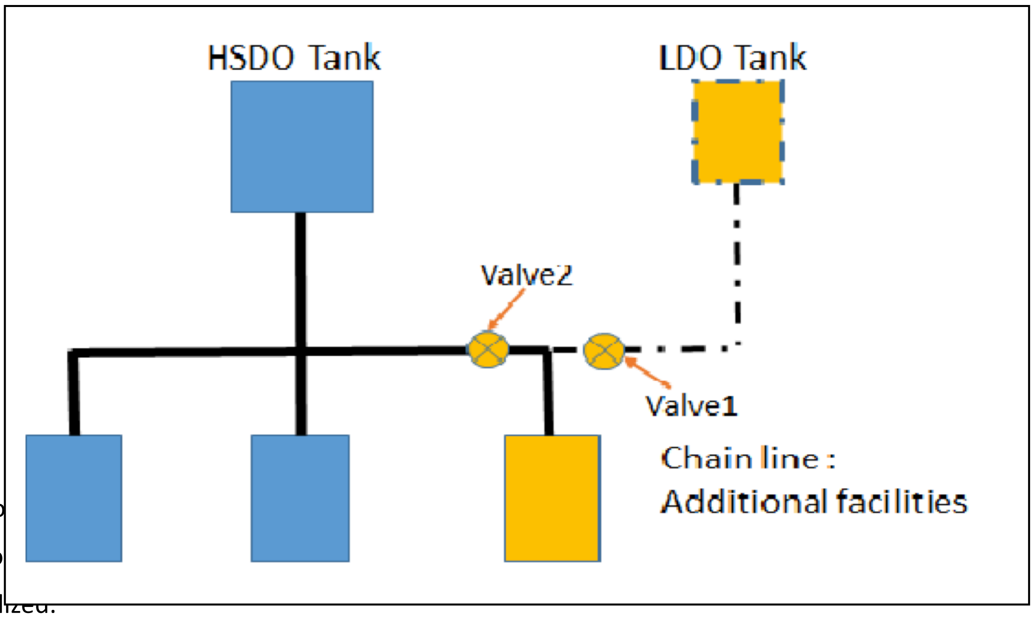
The cetane index digitized the ignition performance. The fuel with the high cetane index has good ignition performance. It's a carbon residue 02 to have to pay attention most in the item inserted in the top. When it's expensive, this makes a filter clogged and an engine stopped.

6-4. Specification of the fuel oil for diesel engine

Items	Specification		Notes
	HSDO	LDO	
The flash point	More than 50℃	More than 60℃	
Pour point	Less than 2.7℃	Less than 5℃	
Kinetic viscosity	More than 2.7cst	Less than 20cst	On 50℃
Carbon residue	Less than 0.1%	Less than 4%	By mass
Water	Non	Less than 0.3%	By Volume
Sulfur	Less than 0.001%	Less than 2.0%	By mass
Specific gravity	Less than 0.85	Less than 0.85	
Cetane index	More than 45	More than 45	Usually 50 to53
Not heating value	42,700 kJ/kg		

6-5. Installation of the LDO fuel line

Before the trial operation by LDO the tank and fuel oil line should be installed as follow.



6-6. Trial o

The trial o

widely util

Trial operation should be operated by HSDO at first and change to LDO after 30 min.

When trial run by LDO, it's important to confirm whether there isn't abnormality in the burning state first.

The checking method with the plainest burning state is observation of the release of smoke state. When normally burning, release of smoke isn't done.

Preparations of radio-thermometer are necessary at least as a measuring machine. The exhaust temperature is gauged with radio-thermometer and it's confirmed that it isn't different from the HSDO driving time in an identical load.

When a load is in the reach of 300degC-400degC at about 50 %, may be judge that the state of the engine is normal.

6-7. The importance of the maintenance

- The engine is defiled faster in the case of using LDO than the case of using HSDO. Therefore, maintenance interval is shortened in the case of using LDO.
- Maintenance interval for HSDO and LDO is shown below table
- The item to which attention is necessary in particular is an exchange of a fuel filter.
- When an exchange of a filter is neglected, an engine stops by clogging. Water is also included in the fuel, but it's also necessary to pay attention to dew condensation in the tank. Once a day, discharge a drain. Water is the factor which makes fuel
- Maintenance interval

No	Maintenance item	Maintenance interval	
		Use of high speed diesel oil (HSDO)	Use of light diesel oil (LDO)
1	Draining water from the fuel service tank	—	Every day
2	Cleaning inside of the service tank	—	Every one year
3	Replacement of fuel oil filter	300hrs	200hrs
4	Replacement of lubricant oil filter	300hrs	200hrs
5	Washing filter of the turbocharger	300hrs	200hrs
6	Replacement of lubricant oil	300hrs	200hrs
7	Washing the oil cooler	At oil temperature rise (Max. 110-120 ℃)	
8	Washing the outside of radiator	1,000hrs	1,000hrs
9	Washing the inside of radiator	4,000hrs	4,000hrs
10	Opening maintenance of the turbocharger	6,000hrs	4,000hrs
11	Opening maintenance of the cylinder head	8,000hrs	6,000hrs
12	Overhaul (pulling out pistons)	16,000hrs	12,000hrs

M-7 Reduction of delivery pressure of compressors

1. Outline:

1.1 Problems

Compressed air is used in crank press machines dispensers, paint spray, air cylinders and products air tight test in this factory. Required air pressure is maximum 8 bar and minimum 4 bar as shown Table 1. Delivery air pressure is set at 8 bar as required by products air tight shop.

Table 1 required pressure of equipment

No.	Equipment	Required pressure (bar)
1	Press machine	6 bar
2	Dispenser	4 bar
3	Painting spray	3 bar
4	Air blow	3 bar
5	Air tight test	8 bar

2. Improvement measures

Energy conservation will be promoted by lowering delivery air pressure of compressor.

Improvement plans are as follows:

(1) Installation of booster compressor and reduction of delivery air pressure of compressor to 6 bar as shown in Figure 1.

(2) Installation of small size compressor for air tight test shop and reduction of delivery air pressure of compressor to 6 bar as shown in Figure 2

Finally, a small-sized air compressor of 2.2 kW is installed for air tight test shop, because a booster air compressor is difficult to purchase in Pakistan.

The delivery pressure of main line air compressors is reduced to 0.7 bar abs. from 0.9 bar abs.by introduction of a small-sized air compressor of 2.2 kW.

Relationship between delivery pressure and power consumption of compressors is shown in Figure 3.

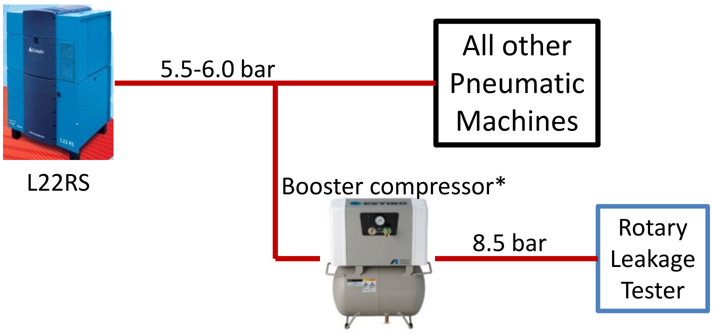


Figure 1 Installation of booster compressor

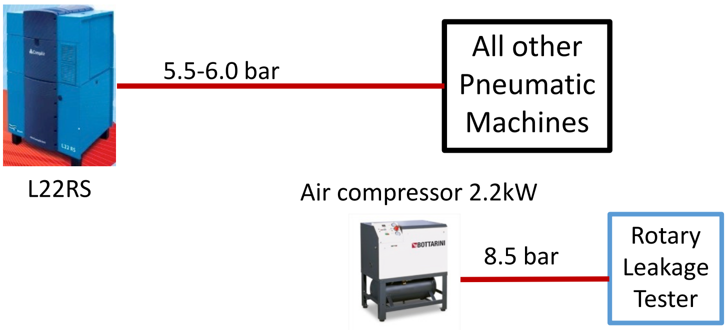


Figure 2 Installation of high pressure air compressor

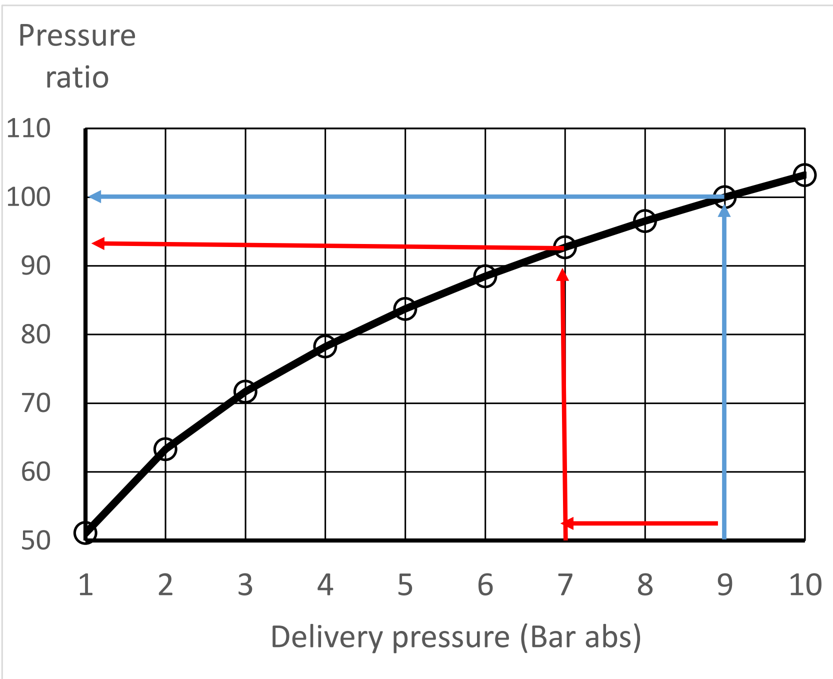


Figure 3 Relationship between delivery pressure and power consumption of compressors

3. Effect estimation

3.1 Calculation formula

Power consumption reduction (kWh/year) ＝ Compressor power consumption in the baseline situation(kW) x energy-saving rate by reduction in discharge pressure (%) x operation hours(h/year)

3.2 Preconditions of estimation

Power consumption saving ratio by changing of delivery air pressure of compressor to 7 bar abs. from 9 bar abs: 8% (based on Figure 3)

Base line power consumption of air compressor: 9.5 kW

Operation hours: 11 hours/ day x 280 days/year = 3,080 hours/ year

Power consumption: 9.5 kW x 3,080 h/y = 29,200 kWh/year

Power tariff: 14 Rs / kWh

3.3 Effect estimation

Power reduction ratio: 8% according to delivery air pressure reduction

Power consumption reduction = 29,200 x 0.08 = 2,330 kWh/year

4 Effect

Power reduction: 2,330 kWh/year

Cost reduction: 2,330 kWh/year x 14 Rs/ kWh ＝32,600 Rs/year

M-8 Heat insulation of heater cylinder of plastic injection molding machine

4. Outline:

4.1 Problems

Heater cylinder surface temperature of plastic molding machines is 200^{o}C. Heat dissipation is large. Section of the heater cylinder is shown in Figure 1.

4.2 Measures

Heat insulation works for heater cylinders are implemented to reduce the surface temperature. Heater cylinder size is 120mm diameter and 700mm length.

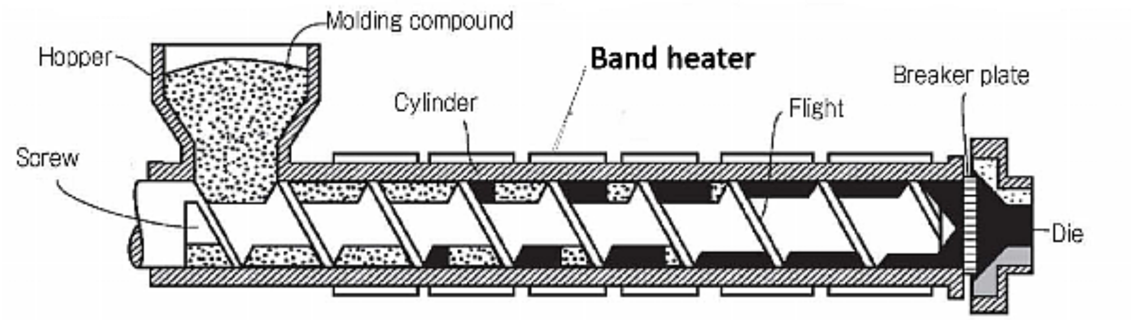


Figure 1 Section of heater cylinder of plastic injection molding machine

5. Improvement

Surface of heater cylinder is covered with insulation jacket of glass fiber mat of 20mm thickness as shown in Figure 2.

Heater jacket specifications are as follows:

- Insulation material: High density glass mat, 20 mm thickness, heat resistance of 600^{o}C, Heat conductivity = 0.032 kcal/h/m/^{o}C
- Outer cover: Silicon coated glass cloth, heat resistance of 400^{o}C
- Inner cover: Heat resistance glass cloth, heat resistance of 600^{o}C
- Model No. Cylinder heat jacket, standard type manufactured by Trend Sign Co. Ltd., Japan
- Installation cost: Rs 40,000.-

Figure 2 Insulation jacket of heater cylinder

6. Effects estimation

6.1 Measurement of surface temperature and power consumption

(1) Surface temperature of heater cylinder and insulation jacket

Surface temperature after heating up time shows in Table 1.

Table 1. Surface temperature of heater cylinder and insulation

Surface	Thickness of insulation (mm)	Surface temperature (^{o}C)
Heater cylinder	0	180 -210
Glass fiber jacket	20	50 - 70

(2) Power consumption of heater cylinder

Power consumption of heater cylinder is calculated from measurement data of total power and hydraulic unit power. Power consumption of heater cylinder is 3 kW after heating-up time, which takes 4 kW of hydraulic power from 7 kW of total power. Power consumption curve is shown in Figure 3.

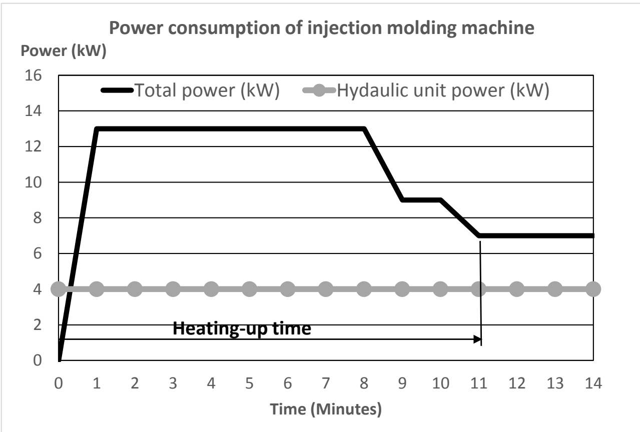


Figure 3 Power consumption of injection molding machine

6.2 Calculation formula

Heat loss of surface of heat cylinder and insulation jacket is radiation heat (Qr) and convection heat (Qc).

Radiation heat loss is shown in the following formula.

Qr (kcal/h) = $4.88 \times \varepsilon \times A \times ((t1 + 273) / 100)^4 - ((t2+ 273) / 100)^4)$

Where ε = Exterior surface emissivity, A = Surface area (m2),

t1 = Surface temperature (^{o}C), t2 = circumstance temperature (^{o}C)

Convection heat loss is shown in the following formula.

Qc (kcal/h) = α x A x (t1 – t2)

Where α = Convection heat transfer rate (kcal/m^2/h/^oC)

Total heat loss = Qr + Qc

Qr is negligible compared with Qc under the condition of less than 200^oC of surface temperature, therefore heat loss is calculated with Qc.

6.3 Precondition of estimation

(1) Heat loss of heater cylinder

α = 12.88 kcal/m^2/h/^oC, t1 = 200^oC, t2 = 30^oC,

Surface area of heater cylinder = 3.14 x diameter x length = 3.14 x 0.12 x 0.7 = 0.264 m^2

Electricity conversion rate = 860 kcal/kWh

Operation hours = 24 hour/day x 0.7 x 312 day/year = 5,240 hours/year

Electricity tariff = 18 Rs/kWh

(2) Heat loss of insulation jacket

α = 7.77 kcal/m^2/h/^oC, t1 = 60^oC, t2 = 30^oC,

Surface area of insulation jacket = 3.14 x diameter x length = 3.14 x 0.16 x 0.7 = 0.352 m^2

Electricity conversion rate, operation hours and electricity tariff are same as that of heater cylinder.

6.4 Effects estimation

Heat loss in current situation: Q_{200} = 12.88 x 0.264 x (200 – 30) = 578 kcal/h = 0.67 kWh

Heat loss after improvement: Q_{60} = 7.77 x 0.352 x (60 – 30) = 82 kcal/h = 0.1 kWh

Power saving effects: Q_{200} - Q_{60} = 0.67 – 0.1 = 0.57 kWh

Power consumption reduction = 0.57 x 5,240 = 2,980 kWh/year

7. Effect

Power consumption reduction: 2,980 kWh/year

Cost reduction: 2,980 kWh/year x 18 Rs/kWh = 53,600 Rs/year

Payback year of investment: 40,000 / 53,600 = 0.75 year

M-9 Reduction of High Pressure Air Loss

General Outline

The plant is producing several kinds of automobile parts. Two compressors are installed for operation of processing machineries, injection molding machines, high pressure die cast machines, and others. In surveying air piping system, decrease rate of air pressure, air leakage, and air pressure of each location, it became apparent that there were much air leakage from air piping system and air pressure loss in piping. And thus, patching of air leakage and widening of air pipe diameter were planned to streamline the activities of compressors and to reduce electricity consumption.

Items for improvement

1) Detection of air leakage points and patching the air leakage points. And continuing air leakage detection in weekly inspection job.

2) Replace the compressed air piping of 1/2" with 1" to reduce pressure loss in CNC-production shop.

Photo 1 1" pipe was installed additionally.

Improvement effect

1) Air leakage ratio to air delivery volume reduced significantly from 9.1% (May 2016) to 5.2% (Nov. 2016) of air delivery volume.
2) . Electricity consumption of compressors decreased by 22,850 kWh/year.
3) Pressure loss by piping at CNC shop became smaller from 0.6 to 0.28.

Calculation of Improvement

1) Air leakage

Figure1 shows pressure leakage measuring data after improvement (Nov. 2016)

Air leakage volume (m^3/min)

= (Pressure difference) x (Inner volume of piping) / (time) / (outer pressure)

= (7.32-6.8) x 6.1 / 8 / 1 = 0.39 (m^3/min)

Air leakage ratio (%)

= (Air leakage volume (m^3/min)) / (Air delivery volume (m^3/min)) x 100

= 0.39 / 7.5 x 100 = 5.2 (%)

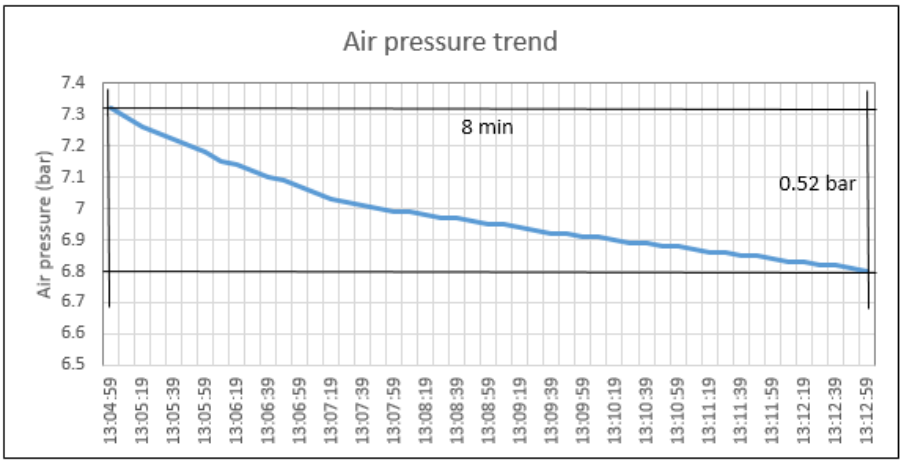


Figure1 Measurement of air pressure reducing trend

at outlet of compressor during no air use in plant.

2) Electricity saving by air leakage reduction

Calculation of electricity reduction (kWh/year)

= 241,769 x 11.6 – 99,871 x 5.2 = 22,850 (kWh/year)

M-10 Improvement of boiler combustion air ratio

8. Outline:

8.1 Problems

Boiler exhaust gas has low oxygen concentration (low air ratio), but high carbon monoxide level of 6,000 ppm or more and high temperature of 441^{o}C, which means that there is significant exhaust gas heat loss as shown in Figure 1. Thermal efficiency is 80%.

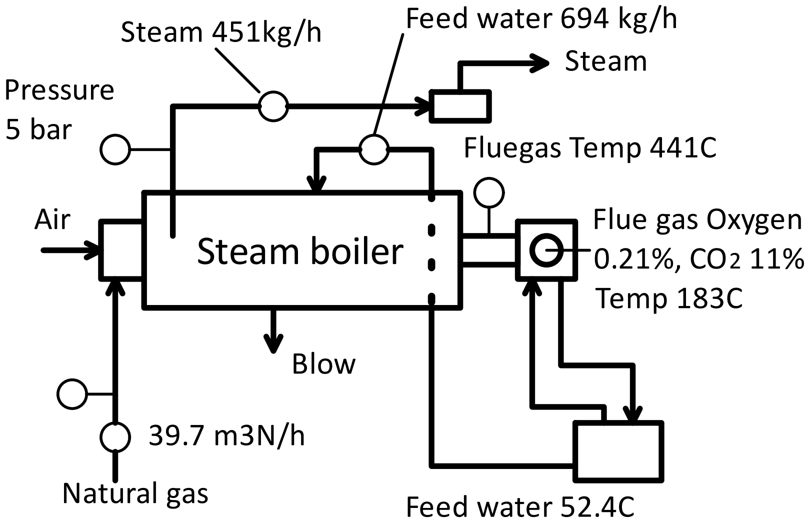


Figure 1 Current operation condition

9. Improvement measures

Energy conservation will be promoted by reinforcing combustion control and adjusting the air ratio.

Air ratio is adjusted by measurement of exhaust gas and repairing of sight hole. As a result of air ratio improvement, exhaust gas temperature is lowered.

Thermal efficiency is improved to 87% from 80%

The results of improvement are shown in Table 1.

Table 1 Improvement of boiler efficiency

	Oct. 2015	Apr. 2016	Nov. 2016	Improved items
Oxygen concentration (%)	0.21	4.74	6.9	Resolution of incomplete combustion
Excess air ratio	1.0	1.29	1.5	
CO concentration (ppm)	6000 or over	0	18	
Flue gas temperature (degC)	441	200	200	Reduction of exhaust heat loss
Boiler efficiency (%)	80.4	88.6	87.1	Improvement of efficiency
Overall efficiency (%)	91.0	91.9	92.0	Heat recovery by economizer

10. Effect estimation

10.1 Calculation formula

Fuel consumption reduction (m^3N/year) = Fuel consumption in the current situation ((m^3N/year) x Reduction ratio.

3.2 Preconditions of estimation

Oxygen concentration level in exhaust gas: 0.21% in the current situation (air ratio ＝1.01), and 6.9% after improvement (air ratio =1.5)

Exhaust gas temperature: 441°C in the current situation, and 200 °C after improvement

Boiler efficiency: 80% in the current situation, and 87% after improvement

Fuel consumption in the current situation: Natural gas 261,600 m^3N/y

Natural gas unit price: 20 Rs/ m^3N

4.3 Effect estimation

Fuel reduction ratio: 7% according to boiler efficiency improvement

Fuel consumption reduction = 261,600 * 0.07 = 18,300 m^3N/year

5 Effect

Fuel reduction: 18,300 m^3N/year

CO_2 reduction:

Cost reduction: 18,300 m^3N/year x 20 Rs/ m^3N =366,000 Rs/year

M-11 Use of natural light

General Outline

The plant is producing automobile filters from raw materials to final products. Solar light cannot penetrate into the plant building sufficiently. To get sun light for illumination several transparent plastic panels are used as roof panels, and well illumination was obtained successfully. However, dust has deposited on the plastic panels, and lighting panel lamps even in daytime is necessary. There cleaning plastic panels were implemented for making a recovery of strength of solar light in daytime.

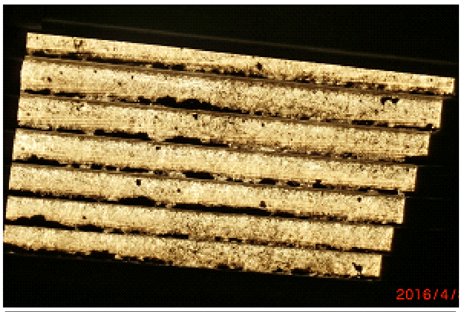
Items for improvement

1) Cleaning transparent plastic roof panels in press shop.

Improvement effect

1) 25 energy savers (85W) can be switched off during day time

2). Energy saving is 5740 kW/year and it costs 103,300 Rs/year.



Plastic roof panes on which dust piled up

Additional lamps are necessary before roof panel cleaning

Illuminance in working space before and after cleaning roof panels (Unit: Lx)

Position in factory	1	2	3	4	5
Before cleaning with lamps	150	116	154	150	190
After cleaning	1380	1530	1185	1150	1300

M-12 Improvement of compressed air leakage

11. Outline:

11.1 Problems

2 sets of air compressor of 22kW and 11 kW are operated. Air leakage volume is 0.42 m3/min, that is 13 % of total delivery air volume of compressors. And also air leaked pipe joints are found with soap water inspection as shown in Figure 1.

Figure 1 Soap water inspection and soap bubbles from air leakage pipe joints

12. Improvement measures

Energy conservation will be promoted by repairing air leakage joints and checking periodically by managers. This factory repairs air leakage joints, gives 1600 joints tag numbers and prepares check list of tag numbers. Maintenance persons check each joint every 3 months and repair leakage points. Fig 2 shows tags of pipe joints. As a result of maintenance effort, air leakage ratio is improved to 3.7% from 13% as shown in Figure 3.

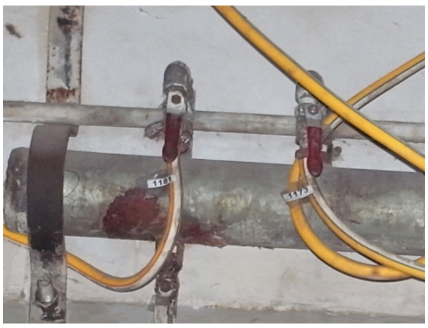


Figure 2 Tags of pipe joints

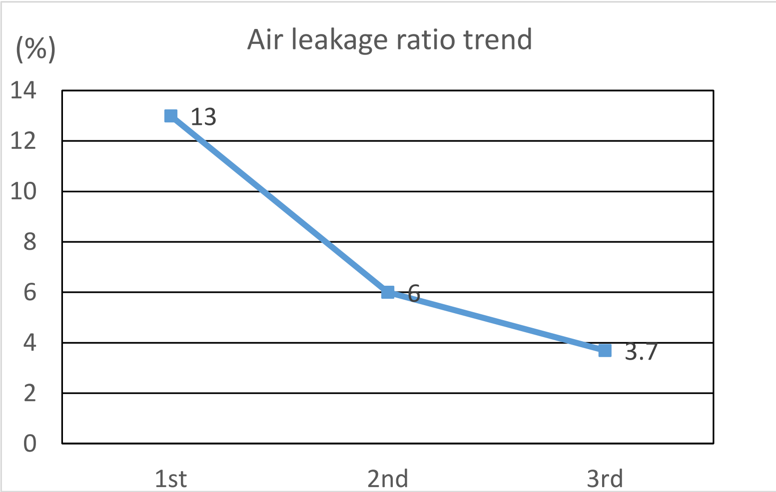


Figure 3 Trend of air leakage ratio for 1 year

13. Effect estimation

13.1 Calculation formula

Theoretical required power of air compressor: La (kW) = 5.718 x Qs x ($Pd^{0.29}$ - 1)

Power consumption is directly proportional to delivery air volume.

Power consumption reduction (kW) = base line power consumption of air compressor (kW) x Reduction ratio

3.2 Preconditions of estimation

Air leakage ratio in the baseline situation; 13 %, and 3.7% after improvement

Base line power consumption: 9.5 kW

Operation hours: 11 hours/ day x 280 days/year = 3,080 hours/ year

Power consumption: 9.5kW x 3,080 h/y = 29,200 kWh/year

Power tariff: 14 Rs / kWh

5.3 Effect estimation

Power reduction ratio: 9.3% according to air leakage improvement

Power consumption reduction = 29,200 x 0.093 = 2,430 kWh/year

6 Effect

Power reduction: 2,430 kWh/year

Cost reduction: 2,430 kWh/year x 14 Rs/ kWh ＝34,000 Rs/year

M-13 Improvement of aluminum melting furnace

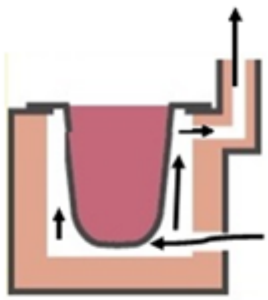
General Outline

The plant is producing several kinds of automobile metal parts and plastic products. Main production procedures are aluminum high pressure die casting, machine processing and plastic injection molding.

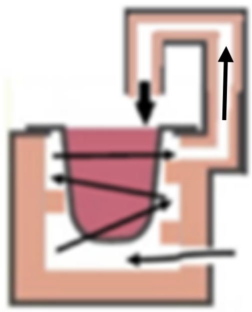
In aluminum high pressure die casting process, aluminum melting is not well developed and much defects of energy saving are existing in the process.

Items for improvement

1) Combustion flame runs shortly to chimney and root of chimney was heated to be red.
2) Red flame blasts out from the top of chimney.
3) Combination of burner and furnace fire hole was not well matched.
4) Structure of furnace was redesigned using spiral flame flow and U-turn chimney to improve above troubles.



Original furnace and flame flow



Spiral flame flow & U-turn chimney

Improvement effect

1) Melting time is reduced from 4.5 hours to 3 hours. Therefore, energy efficiency increased by 1.5 times.
2) Fuel consumption decreased by 1/3.

Calculation of Improvement

1) Presuming average natural gas consumption is 20,000 m^3/month, annual natural gas saving is calculated as below.

Annual natural gas saving (m^3/year)

= 20,000 x (1/3) x 12 = 80,000 (m^3/year)

M-14 Replacement of degreasing bath heating burner

General Outline

The plant is producing several kinds of automobile parts. Zinc plating process is featuring this plant. Degreasing is an important process as pretreatment for keeping quality of electroplated film. Degreasing bath is heated with LPG gas. Flame of combusting gas was reddish and not powerful.

Items for improvement

Gas pressure and air ratio were controlled, but combustion situation was not improved.

Then a new Bunsen type burner was installed, and gas pressure and air ratio were controlled.

Before replacement

New burner

Improvement effect

1) Flame color changed from reddish to blueish.
2) Form of flame changed to be sharp and powerful.
3) Heating up time has become shortened.
4) Generation of toxic CO gas must be reduced. (Not measured)

Calculation of Improvement

Burner	Days	LPG consumption (kg)	LPG daily consumption (kg)
Before replacement	50	360	7.2
New burner	43	225	5.23
		Reduction of daily consumption (kg)	1.97

Annual LPG consumption reduction: 1.92 x 25 x 12 = 590.23 (kg/year)

M-15 Improvement of air blow

14. Outline:

14.1 Problems

Air blow is very effective device to clean surface of machining metal, cast sand molds etc., but air consumption is large. A cast iron factory use air blow guns and rubber hoses to clean sand molds, Air consumption of air blow shares 62% of delivery air volume of 2 sets of compressor of 45kW. Nozzle diameter of air blow guns is 8 mm and diameter of rubber hoses is 10 mm as shown in figure 1, therefore large volume of air is consumed to air blow work.

15. Improvement measures

Energy conservation will be promoted by changing nozzles of air blow guns and rubber hoses.

15.1 Change of air blow guns

10 sets of air blow gun of 8mm diameter nozzle are changed to that of 2mm diameter nozzle as shown in Figure 2. Air consumption is reduced by changing nozzle diameter of 8mm to 2mm as shown in Table1.

Figure 1 Air blow gun with 8mm dia. nozzle

Figure 2 Air blow gun with 2mm dia. nozzle

Table 1 Effects of reduction of nozzle diameter of air blow gun at air pressure of 5 bar

Air nozzle	Nozzle diameter	Air consumption at base line	Air consumption after improvement	Change of impact pressure at 100mm
Air blow gun	8 mm to 2 mm	3.3 m^3/ min	0.2 m^3 /min	0.14 MPa to 0.01 MPa

Power consumption of air compressor is reduced by 40% by changing nozzle diameter of 8mm to 2mm based on monitoring of air blow guns use.

16. Effect estimation

16.1 Calculation formula

Theoretical required power of air compressor: La (kW) = 5.718 x Qs x ($Pd^{0.29}$ - 1)

Power consumption is directly proportional to delivery air volume.

Power consumption reduction (kW) = base line power consumption of air compressor (kW) x Reduction ratio

3.2 Preconditions of estimation

Air consumption saving ratio by changing of nozzle diameter; 40 %

Base line power consumption of air compressor: 46.5 kW

Air consumption ratio of air blow guns: 62%

Power consumption of air blow guns: 46.5kW x 0.62 = 28.8 kW

Operation hours: 10 hours/ day x 300 days/year = 3,000 hours/ year

Power consumption: 28.8 kW x 3,000 h/y = 86,400 kWh/year

Power tariff: 17 Rs / kWh

6.3 Effect estimation

Power reduction ratio: 40% according to air blow gun nozzle change

Power consumption reduction = 84,400 x 0.4 = 33,700 kWh/year

7 Effect

Power reduction: 33,700 kWh/year

Cost reduction: 33,700 kWh/year x 17 Rs/ kWh ＝573,000 Rs/year