CASE STUDIES – CS 4

Segment – Affinity Laws \ Pumping System

Topic/ case – Cooling water pumps at coke oven, Tata Steel –

Low discharge due to high pressure drop across chillers

Description of the case – Tata Steel has installed 10”/12” size cooling water pump in their coke plant.

The rated discharge of the pumps was selected such that the required discharge could be obtained from two pumps, while the others could be used as stand-by units. In practice, however, they have to run at least four pumps to get the required flow rate. Investigation revealed that the large pressure drop across the chillers has moved the system curve to a higher level of head. The company is considering refurbishing the cooling coils in the chillers to reduce system loss and also, at the same time, using larger impellers to improve the flow from each pump.

Question for discussion-

2. What are the diagnostic steps to determine the actual head and capacity of the pumps in operation?
3. How do we determine the new impeller diameter of the existing pumps for larger head?
4. How do we draw the new pump H-Q and new system curves and estimate flow from each pump?

Pump System Data Provided by Tata Steel

A. Condenser Pump Details :

- Pump Make – Kirloskar Brothers
- Model No – 10UPH2
- No. of Pumps – Four (3 Working + 1 Stand by)
- Rated Capacity of Each Pump – 247.22 Lps = 890 M^3/Hr.
- Rated Head of Each Pump – 27.0 M
- Rated Impeller Dia. = 347 mm
- Motor Rating – 90 kW, 4 Pole, 50 Hz

B. Flow Measured by Ultrasonic Flowmeter :

- Flow Obtained from Pump 1 = 326 M^3/hr.
- Flow Obtained from Pump 2 = 245 M^3/hr.
- Flow Obtained from Pump 3 = 305 M^3/hr.

  Total Flow Obtained = 876 M^3/hr.

  Therefore, Average Flow per Pump = 292 M^3/hr.

C. Delivery & Suction Pressure Gauge Readings of Each Pump :

- Delivery Pressure of each pump = 0.4 kg/cm^2
- Suction Pressure of Each Pump = 0.4 kg/cm^2

  Differential Pressure = 3.6 kg/cm^2

  Total Head Developed by Each Pump = 36 M (Neglecting Velocity Head)

D. Inlet & Outlet Pressure of Chiller-Condensers :

Chiller Unit 1

- Inlet Pressure = 3.8 kg/cm^2
- Outlet Pressure = 1.2 kg/cm^2

Therefore, Head drop across Chiller Unit 1 is 26 M

Chiller Unit 2

- Inlet Pressure = 3.8 kg/cm^2
- Outlet Pressure = 1.5 kg/cm^2

Therefore, Head drop across Chiller Unit 2 is 23 M

Chiller Unit 3

- Inlet Pressure = 3.8 kg/cm^2
- Outlet Pressure = 1.8 kg/cm^2

Therefore, Head drop across Chiller Unit 3 is 20 M

Avg. head drop across chiller unit is 23 M.

E. Establishing the System resistance Curve for the Existing System:

The total head of the pumping system and the system resistance curve under the existing condition is established in the following manner:

- Head Developed by each pump = 36 M
- Avg. flow from each pump = 292 M3/Hr.
- Friction Head drop in the discharge pipe between pump & chiller condenser(avg.) = 2 M
- Friction Head drop in the piping beyond the chiller condenser up to cooling tower = 3 M (assumed)
- Total friction head drop in the system corresponding to 876 M3/Hr.

- Static Head = Total Head – Frictional Head Drop = 36 – 28 = 8 M
- Therefore, the system components for the existing situation are as follows:
- Static Head = 8 M
- Friction Head = 28 M
- From the above data the present system curve can be drawn noting that friction loss varies as the square of the flow.

F. Establishing the Duty for the New Pumps :

- Design flow of each condenser unit = 470 M3/Hr.
- Established Head drop across each condenser unit when flow increases from 292M3/hr. to 470M3/Hr. = (470/292)2 x 23 M = 59 M
- Friction head drop across the piping when total flow increases from 876M/Hr. to 3x470M/Hr. or 1410 M3/hr. = (1410/876)2 x 5 = 13 M

Therefore, total friction head in the system corresponding to 1410M3/hr. = 59 + 13 = 72 M

Static Head = 8 M

Therefore, pump total head corresponding to 1410 M3/hr. is 80 M

If two pumps is operated in parallel to serve the present duty, then rated flow of each pumps becomes = 705 M3/hr.

Rated flow for each pump is considered 750 M3/Hr and total head is 80 M.

G. Root Cause Analysis & Possible Remedies:

<u>The Reason for the Present Problem:</u>

Data collected by user quite clearly shows that increased frictional head drop in the chiller condenser units has resulted in large increase in the system head. Consequently, pumps are made to operate far to the left of their rated design duty point on the H-Q curve. You'll observe from the performance curve of 10UPH2 that even by using a full diameter impeller (375mm) you are unlikely to achieve the design flow under present system condition.

Possible Remedies:

Solution 1 :

Chiller units appear to be the only source of large pressure drop and rectification of the units should solve your problems. Piping external to the chiller units do not show any unusual pressure drop – for example, between pump discharge and chiller inlet the drop is only 0.2 kg/cm2.

Solution 2 :

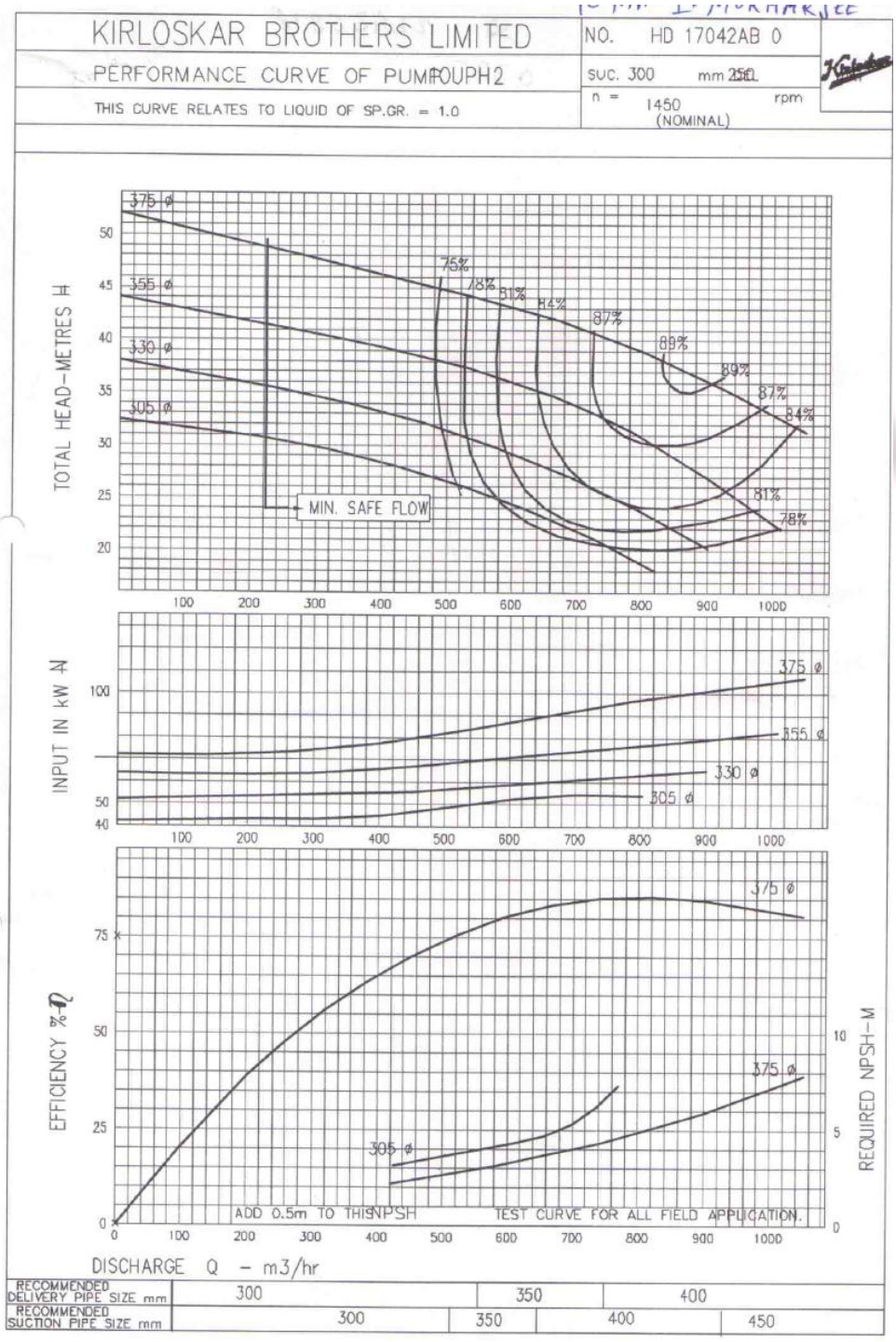
If solution 1 is not feasible immediately, four pumps need to be installed. We have submitted a budgetary offer. However, pump of these specification is also available from Mather & Platt (8/10DME), Kirloskar (8UPH4) etc. it should be noted that this solution can only be adopted if the chiller condenser units are capable of taking inlet pressure of 8.0 kg/cm2. We would strongly recommend that pumps are driven by VFD since once the fouling issue is sorted out, running the pump at 1480 rpm in throttled condition will waste significant amount of energy.

If you need a discussion on this note, please feel free to call me. If required, I will be quite happy to visit your plant to discuss this further.

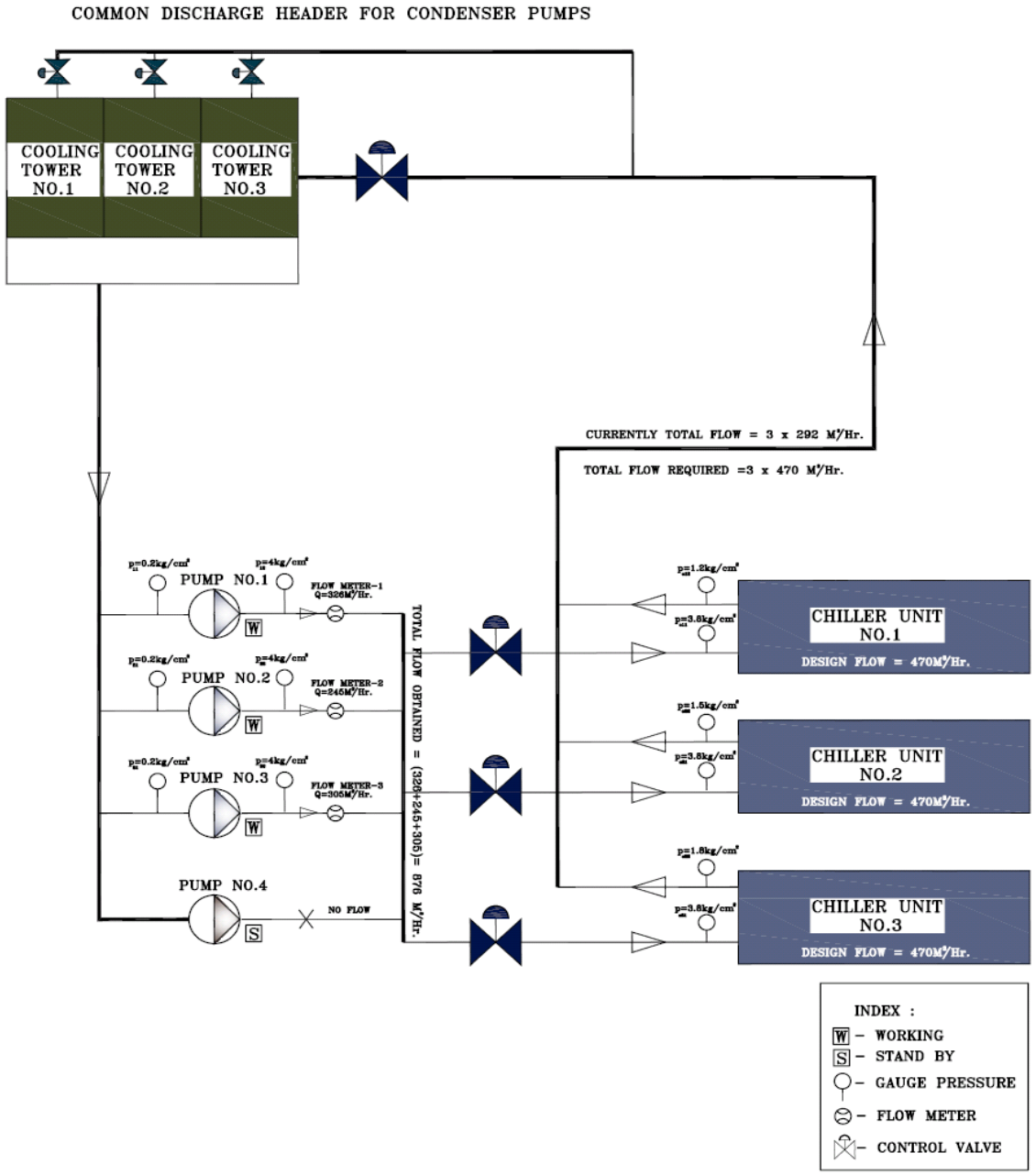
Enclosures:

1) **Annexure 1** – Performance Curve of Kirloskar make pump Model 10UPH2.
2) **Annexure 2 –** A schematic showing the arrangement of four cooling water pumps and chiller condensers in cooling water plant, TISCO.
3) **Annexure 3 –** Pump & system curves showing operation of three pumps running in parallel in your existing system. The system curve has been estimated as per the procedure described above.
4) **Annexure 4 –** Proposal for a new pump, rated 750 M3/Hr.@80 M head. This pump will ensure that when two pumps are operated in parallel each of the three chiller units will receive 470 M3/Hr.
5) **Annexure 5 –** Pump curve and system curves with proposed pump in existing system. The curve demonstrates how the combined flow of 1410 M3/Hr. required by three chiller units will be met by the two pumps operating in parallel.
6) **Annexure 6 –** System curve as per the design head drop across the chillers. Variable speed performance of the new pump is superimposed on the system curve. This curve demonstrates the effort of removing the fouling in the chiller condenser system and how energy can be saved by installing VFD for driving of the new pumps.

Annexure – 1

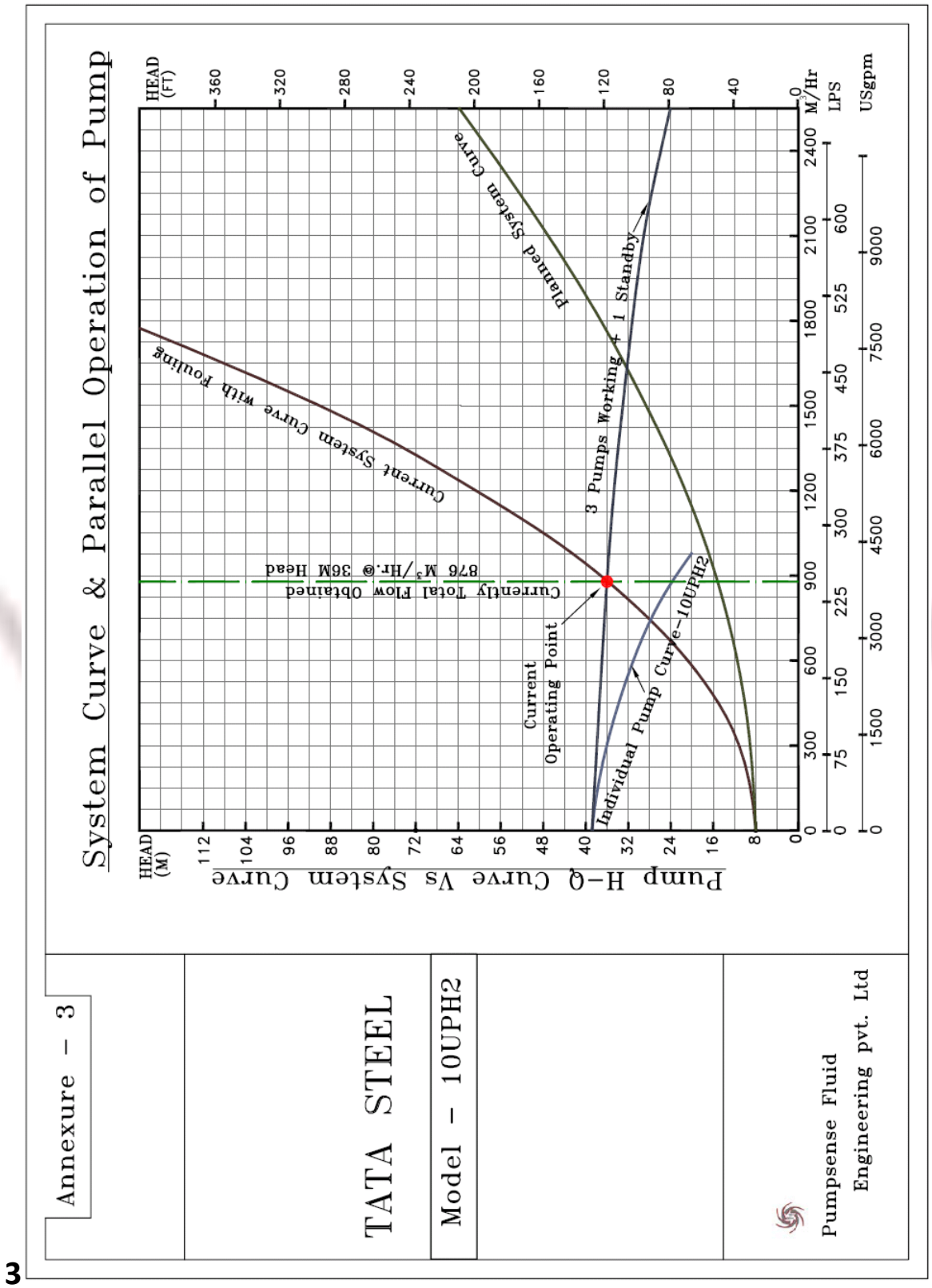

KIRLOSKAR BROTHERS LIMITED
NO. HD 17042AB 0
PERFORMANCE CURVE OF PUMP 10UPH2
SUC. 300 mm DEL.
THIS CURVE RELATES TO LIQUID OF SP.GR. = 1.0
n = 1450 rpm (NOMINAL)
TOTAL HEAD-METRES H
375 ø
355 ø
330 ø
305 ø
MIN. SAFE FLOW
75%
78%
81%
84%
87%
89%
INPUT IN kW
EFFICIENCY %
REQUIRED NPSH-M
ADD 0.5m TO THIS NPSH
TEST CURVE FOR ALL FIELD APPLICATION.
DISCHARGE Q - m3/hr
RECOMMENDED DELIVERY PIPE SIZE mm
RECOMMENDED SUCTION PIPE SIZE mm

Annexure – 2



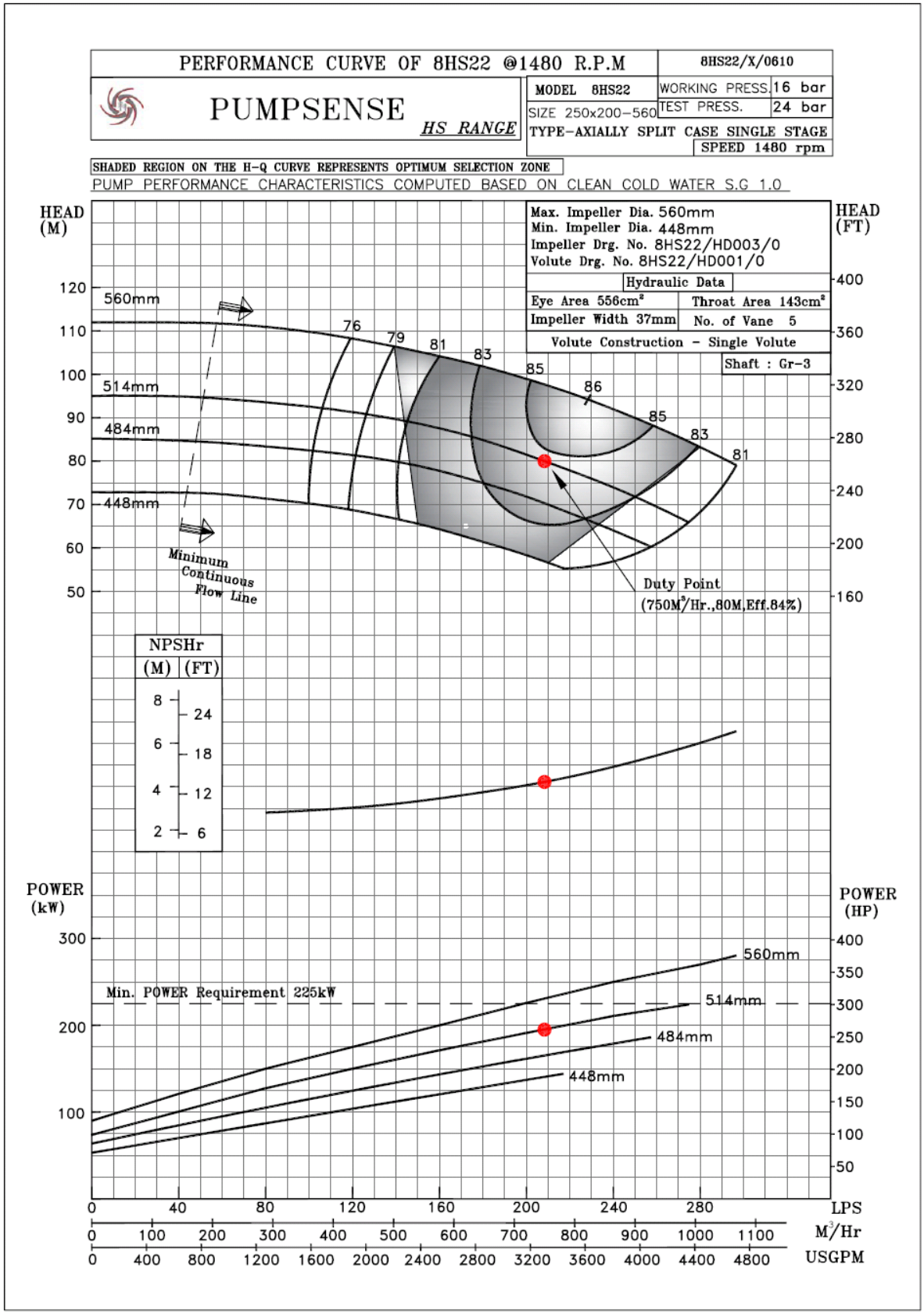
Schematic Showing Major Components of Cooling Water System at Coke Palnt, Tata Steel

Annexure –


System Curve & Parallel Operation of Pump
Pump H–Q Curve Vs System Curve
HEAD (M)
HEAD (FT)
M³/Hr
LPS
USgpm
Current System Curve with Fouling
Planned System Curve
3 Pumps Working + 1 Standby
Individual Pump Curve–10UPH2
Current Operating Point
Currently Total Flow Obtained
876 M³/Hr.@ 36M Head
Annexure – 3
TATA STEEL
Model – 10UPH2
Pumpsense Fluid
Engineering pvt. Ltd

3

Annexure – 4


PERFORMANCE CURVE OF 8HS22 @1480 R.P.M
8HS22/X/0610
PUMPSENSE
HS RANGE
MODEL 8HS22
WORKING PRESS. 16 bar
SIZE 250x200-560
TEST PRESS. 24 bar
TYPE-AXIALLY SPLIT CASE SINGLE STAGE
SPEED 1480 rpm
SHADED REGION ON THE H-Q CURVE REPRESENTS OPTIMUM SELECTION ZONE
PUMP PERFORMANCE CHARACTERISTICS COMPUTED BASED ON CLEAN COLD WATER S.G 1.0
Max. Impeller Dia. 560mm
Min. Impeller Dia. 448mm
Impeller Drg. No. 8HS22/HD003/0
Volute Drg. No. 8HS22/HD001/0
Hydraulic Data
Eye Area 556cm²
Throat Area 143cm²
Impeller Width 37mm
No. of Vane 5
Volute Construction - Single Volute
Shaft : Gr-3
HEAD (M)
HEAD (FT)
560mm
514mm
484mm
448mm
76
79
81
83
85
86
85
83
81
Minimum Continuous Flow Line
Duty Point
(750M³/Hr.,80M,Eff.84%)
NPSHr
(M)
(FT)
POWER (kW)
POWER (HP)
Min. POWER Requirement 225kW
LPS
M³/Hr
USGPM

PUMPSENSE FLUID ENGINEERING PVT. LTD

To,
TISCO
Q1359
13.11.10

PQ/PD/1359

Kind Attention : Mr. Pijush chakrovarty

DATA SHEET FOR CONDENSER WATER PUMP

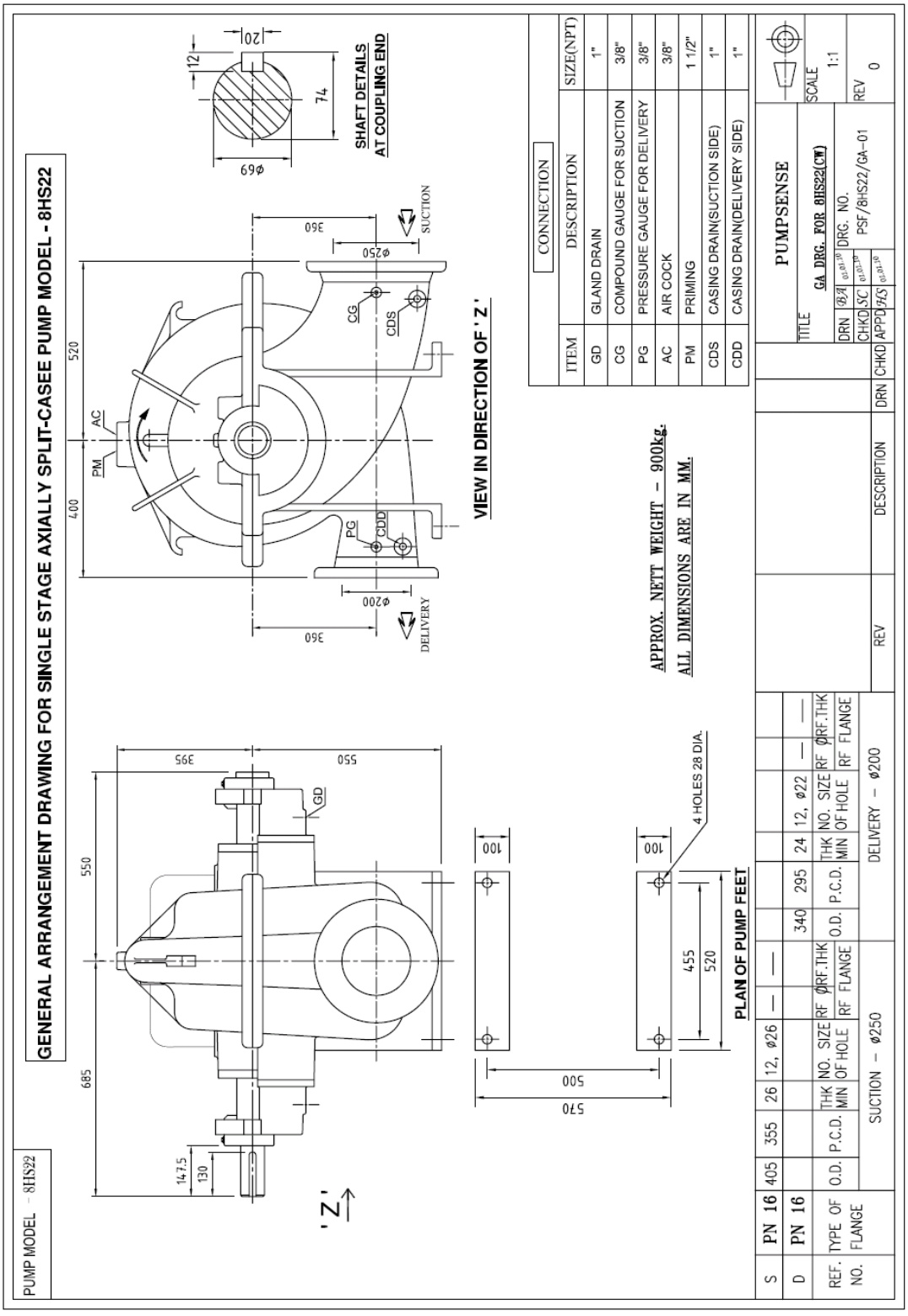
	PARAMETERS	UNIT	ITEM 1
DUTY SPECIFIED	Capacity	m^3/hr	750
	Total Head	m	80
	Speed	rpm	1480
	Type of Pump		Axially Split Case
	Liquid		Clear Water
	Specific Gravity		1
	Temperature	°C	32
	Driver		Electric Motor
	No. off		2

PUMP DETAILS	Make		PUMPSENSE
	Stages		Single
	Model No.		8HS22
	Discharge	mm	200
	Discharge Flange Rating		PN 16
	Suction	mm	250
	Suction Flange Rating		PN 16
	Type of Casing		Single Volute
	Type of Impeller		Shrouded Double Entry
	Impeller Diameter Max.	mm	560
	Impeller Diameter Rated	mm	514
	Impeller Diameter Min.	mm	448

PERFORMANCE DETAILS AT DUTY	Efficiency	%	84
	Speed		1480
	NPSHr	m	4.1
	Power absorbed	kW	194.6
	Recommended Driver Power	kW	225
	Motor Details		4 Pole ,50 Hz, 3 Phase AC Induction

MECHANICAL DATA	Bare Pump Weight	kg	900 Kg (approx)
	Shaft dia. at coupling	mm	69
	N.D.E Bearing		6314
	D.E Bearing		6314

	PARAMETERS	UNIT	ITEM 1
MATERIALS OF CONSTRUCTION	Casing		CI FG260 ASTM A48 Class 35
	Impeller		Bronze LG2 ASTM B584 C83600
	Casing Wear Rings		Bronze LB2 ASTM B584 C93700
	Bearing Brackets		CI FG260 ASTM A48 Class 35
	Shaft		SS ASTM A 388 AISI 410
	Shaft Sleeves/Nuts		Bronze CT1 ASTM B30 C90700
	Sealing Type		Gland Packing
	Glands		Bronze LG2 ASTM B584 C83600
	Lantern Rings		Bronze LG2 ASTM B584 C83600


GENERAL ARRANGEMENT DRAWING FOR SINGLE STAGE AXIALLY SPLIT-CASEE PUMP MODEL - 8HS22
PUMP MODEL - 8HS22
SHAFT DETAILS AT COUPLING END
VIEW IN DIRECTION OF 'Z'
APPROX. NETT WEIGHT - 900kg.
ALL DIMENSIONS ARE IN MM.
PLAN OF PUMP FEET
4 HOLES 28 DIA.
SUCTION
DELIVERY
CONNECTION
ITEM | DESCRIPTION | SIZE(NPT)
GD | GLAND DRAIN | 1"
CG | COMPOUND GAUGE FOR SUCTION | 3/8"
PG | PRESSURE GAUGE FOR DELIVERY | 3/8"
AC | AIR COCK | 3/8"
PM | PRIMING | 1 1/2"
CDS | CASING DRAIN(SUCTION SIDE) | 1"
CDD | CASING DRAIN(DELIVERY SIDE) | 1"
PUMPSENSE
TITLE GA DRG. FOR 8HS22(CW)
SCALE 1:1
DRG. NO. PSF/8HS22/GA-01
REV 0
DESCRIPTION
S PN 16 405 355 26 12, ø26 — — 340 295 24 12, ø22 — — RF ØRF.THK FLANGE
D PN 16
REF. NO. TYPE OF FLANGE O.D. P.C.D. THK MIN NO. SIZE OF HOLE RF ØRF.THK FLANGE O.D. P.C.D. THK MIN NO. SIZE OF HOLE RF ØRF.THK FLANGE
SUCTION - ø250 DELIVERY - ø200

Solution 1

Renovation of Existing System

Rotating Element for Raw Water Pump – Technical Specifications

Introduction – Coke Oven cooling water system at Tata Steel, Jamshedpur, has four cooling water pumps supplied by Kirloskar Brothers Ltd, Pune. The pump casings are in good working order and it is intended to replace the rotating elements of these existing pumps to meet the altered flow and head conditions. The new rotating elements should include energy efficient impellers and ensure at least four years of uninterrupted working life.

Existing Pump – Following is the brief description of the existing pump units:

No of pumps - Four
Make: Kirloskar Brothers Ltd, Pune, India
Type: Axially split case
Delivery / Suction Branch Sizes: 10”/12”
Casing Design: Single volute, side suction, side discharge.
Rated Capacity: 247.22 l/s – 890 m3/hr
Rated head: 27.0 m
Rotational Speed: 1480 rpm
Impeller Diameter – 347 mm
Driver: 90 KW, 4 pole, 50 Hz, 415V TEFC motor

Scope of Work: We have considered the following scope of work:

1. Design and development a new impeller for 650 m3/hr at 42 m total head.
2. Measurement of internal dimensions of the existing pump and rotating element at site in order to clearly establish the site constraints for optimizing the design of rotating element.
3. Design of shaft and other rotating components as per the list of components included in this document.
4. Preparation of final data sheet and of machining drawings for components of the rotating element. Submission of these documents to Tata Steel for their approval and future reference.
5. Manufacture of components based on approved drawings
6. Submission of all quality assurance documents as per the list included in this document.
7. Installation of the rotating element at site. Conducting trial run of the pump with the new rotating element in association with Tata Steel engineers.
8. Demonstrating to Tata Steel that performance guarantee has been met

Components and their material specifications

Sr. No	Component	Material Specifications
1	Impeller	Gun Metal BS1400 LG2
2	Case Wear Rings	Bronze BS1400 LB2
3	Shaft	AISI 410
4	Sleeves and sleeve nuts	Zinc Free Bronze BS1400 CT1
5	Stuffing box bushes	Bronze BS1400 LB2
6	Glands	Bronze BS1400 LG2
7	Lantern ring	Bronze BS1400 LG2
8	Water deflector	Neoprene Rubber
9	Bearings	SKF 6309
10	Gland packing	PTFE

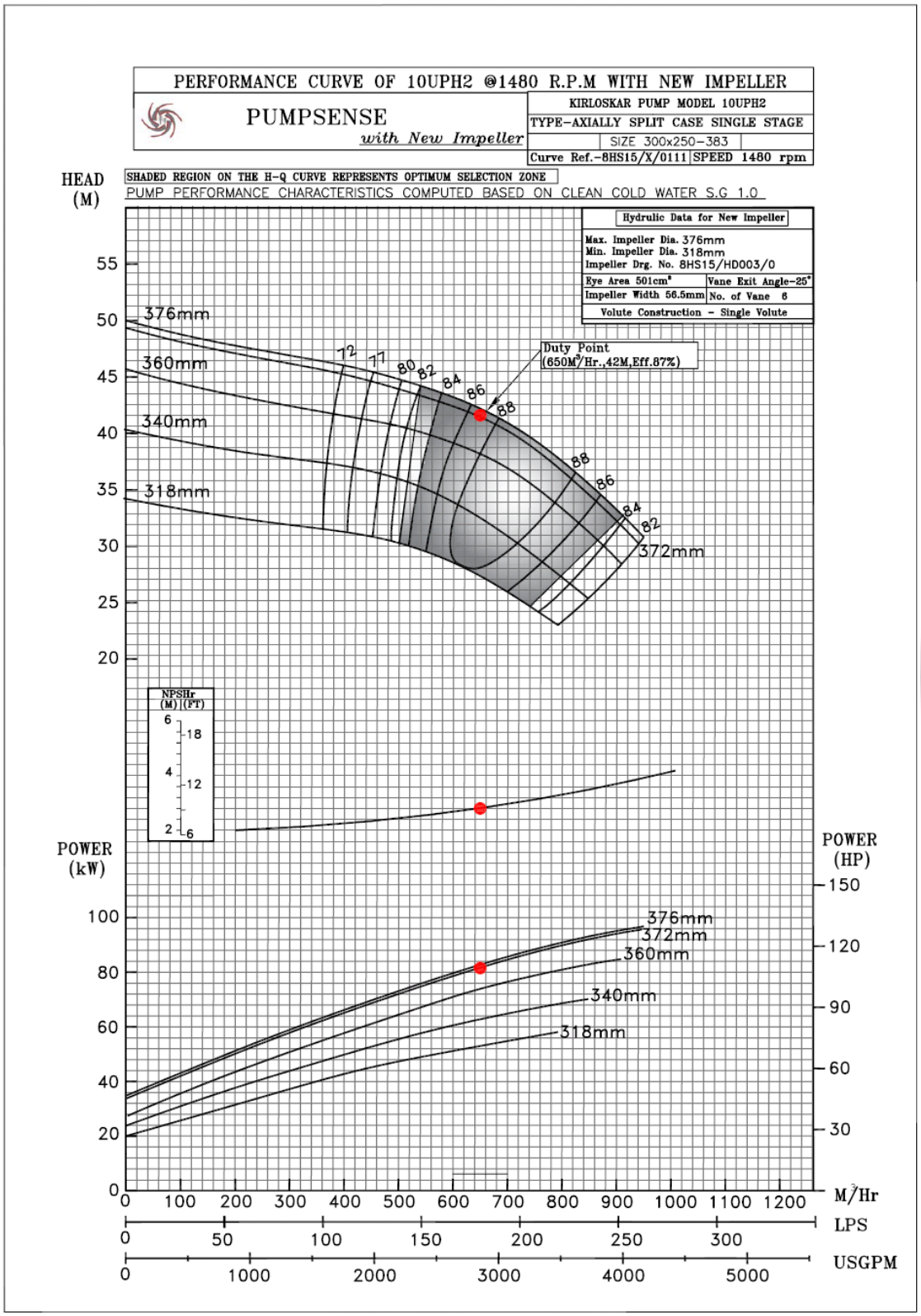
Please note that the above list is indicative only and any additional components / consumables needed to successfully carry out the replacement of the existing rotating element will be in our scope of supply.

Quality Assurance Documents – The following quality assurance documents will be submitted by us:

Component	QA Documents
Impeller	Dynamic balancing report as per ISO 1940 G 6.3 Chemical test report, dimensional report
Shaft	Ultrasonic test report, chemical and physical test report, dimensional report
Wear Rings	Hardness, chemical test and dimensional reports
Shaft sleeves	Chemical test and hardness reports

Data sheets – We are attaching a preliminary data sheets containing key information relating to dimensions of the components and their design features. Preliminary data sheet should be considered indicative only and has been included to indicate our understanding of the design task and the design approach proposed by us. In the event of an order, we willl submit a final data sheet for approval when all of the design elements have been finalised. We, however, confirm that key hydraulic design data – rated capacity, head, efficiency and NPSHR shall not be changed and retained as per the preliminary data sheet.

Meeting performance guarantee – Fulfilment of performance guarantee will be ensured by taking suction and delivery pressure gauge readings and power consumption at the motor terminals for pre-defined number of flow conditions before and after the installation of new rotating element. The method of fulfilment of performance guarantee will be discussed in detail with Tata Steel during pre-award discussions to arrive at mutually agreed procedure.


PERFORMANCE CURVE OF 10UPH2 @1480 R.P.M WITH NEW IMPELLER
PUMPSENSE
with New Impeller
KIRLOSKAR PUMP MODEL 10UPH2
TYPE-AXIALLY SPLIT CASE SINGLE STAGE
SIZE 300x250-383
Curve Ref.-8HS15/X/0111
SPEED 1480 rpm
SHADED REGION ON THE H-Q CURVE REPRESENTS OPTIMUM SELECTION ZONE
PUMP PERFORMANCE CHARACTERISTICS COMPUTED BASED ON CLEAN COLD WATER S.G 1.0
Hydrulic Data for New Impeller
Max. Impeller Dia. 376mm
Min. Impeller Dia. 318mm
Impeller Drg. No. 8HS15/HD003/0
Eye Area 501cm²
Vane Exit Angle-25°
Impeller Width 56.5mm
No. of Vane 6
Volute Construction - Single Volute
HEAD (M)
376mm
360mm
340mm
318mm
372mm
Duty Point (650M³/Hr.,42M,Eff.87%)
NPSHr (M) (FT)
POWER (kW)
POWER (HP)
M³/Hr
LPS
USGPM

PUMPSENSE FLUID ENGINEERING PVT. LTD

To,
TATASTEEL
Q1593-1
25.02.11

HS/TISCO/1593-1

Kind Attention : Mr. Pijush chakrobarty

SERVICE : REPLACEMENT OF ROTATING ELEMENTS OF CONDENSATE EXTRACTION PUMP

	PARAMETERS	UNIT	ITEM1
DUTY SPECIFIED	Rated Capacity	$m^3/hr.$	650
	Rated Head	m	42
	Speed	rpm	1480
	Type of Pump		Axially Split Case Single Stage
	Liquid		Clear Water
	Specific Gravity		1
	Temperature	°C	32
	Driver		Electric Motor

DETAILS OF EXISTING PUMP	Make		Kirloskar Brothers Limited
	No of Pumps		1
	Stages		One
	Model No.		10UPH2
	Discharge	mm	250
	Discharge Flange Rating		—
	Suction	mm	300
	Suction Flange Rating		—
	Type of Casing		Single Volute, Side Suction & Side Discharge

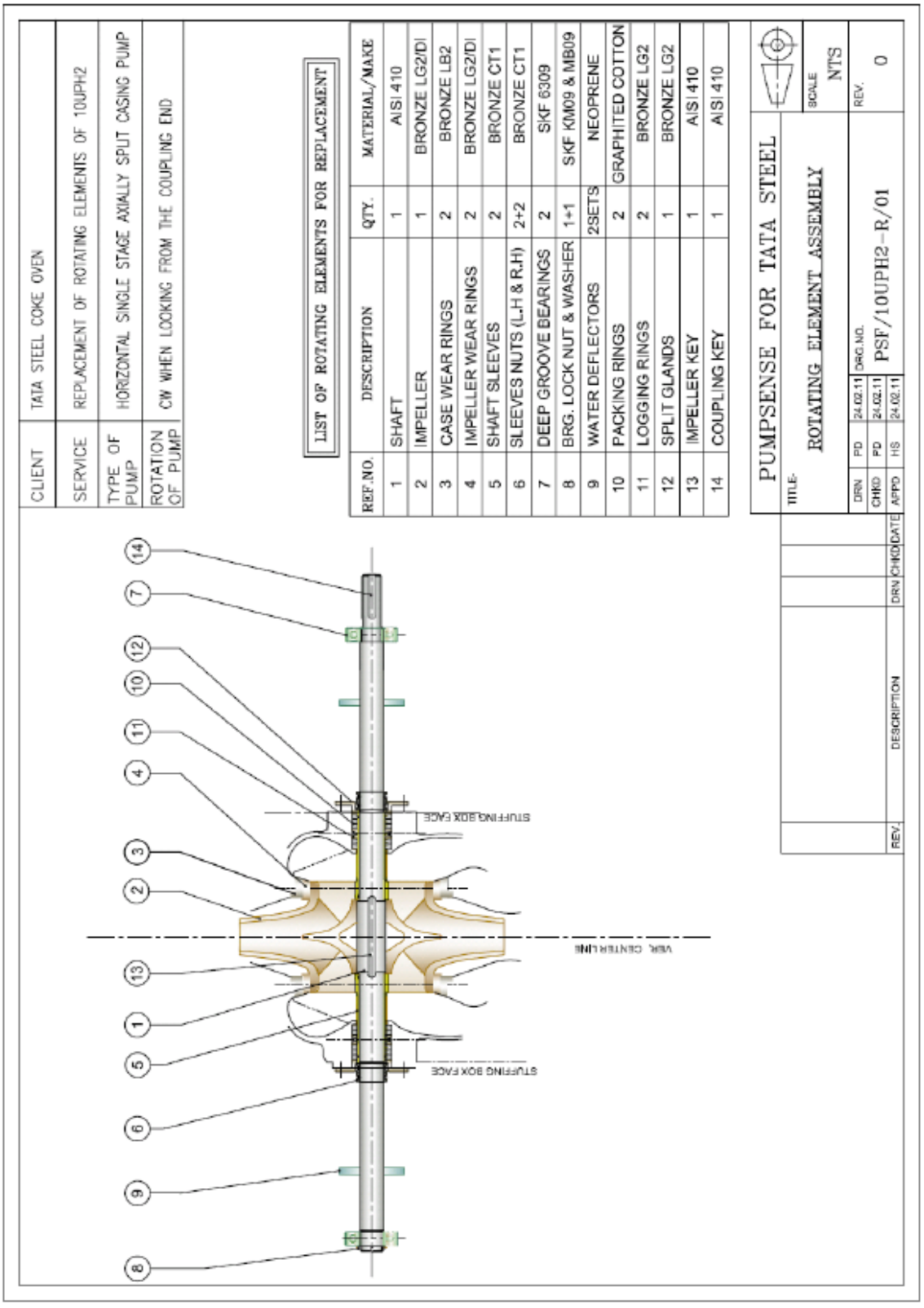
DETAILS OF NEW IMPELLER	Type of Impeller		Shrouded Double Entry
	Impeller Diameter Max.	mm	376
	Impeller Diameter Rated	mm	372
	Impeller Diameter Min.	mm	318
	Impeller Width	mm	56.5
	No. of Vanes		6

Note : Impeller data provided are only preliminary. Final data will be provided after a full investigation of the existing casing and internals

PERFORMANCE DETAILS AT RATED CAPACITY WITH NEW IMPELLER	Efficiency	%	87
	Speed	rpm	1480
	NPSHr	m	2.8
	Power absorbed	kW	85.5
	Driver Power	kW	90
	Driver Details		4 Pole, 50 Hz, 3 Phase AC Induction Motor

MECHANICAL DATA	Shaft Span	mm	To be confirmed after survey
	Shaft Dia. at Coupling	mm	To be confirmed after survey
	N.D.E Bearings	mm	SKF 6309 (to be checked at site)
	D.E Bearings	mm	SKF 6309 (to be checked at site)

	PARAMETERS	Qty	ITEM1
COMPONENTS FOR REPLACEMENT & MATERIAL OF CONSTRUCTION	Impeller	1	Bronze BS 1400 LG2 alternatively Ductile Iron GGG 50
	Casing Wear Rings	2	Bronze BS1400 LB2
	Impeller Wear Rings	2	Bronze BS 1400 LG2 / Ductile Iron GGG 50
	Shaft with Keys	1	AISI – 410
	Sleeves	2	Bronze BS1400 CT1
	Sleeve Nuts	4	Bronze BS1400 CT1
	Split Glands	2	Bronze BS1400 LG2
	Lantern ring	2	Bronze BS1400 LG2
	Water deflector	2	Neoprene Rubber
	Bearings (DE & NDE)	2	SKF 6309
	Lock Nut & Washer	1+1	SKF KM09 & MB09
	Packing Rings	2 Sets	PTFE


CLIENT
TATA STEEL COKE OVEN
SERVICE
REPLACEMENT OF ROTATING ELEMENTS OF 10UPH2
TYPE OF PUMP
HORIZONTAL SINGLE STAGE AXIALLY SPLIT CASING PUMP
ROTATION OF PUMP
CW WHEN LOOKING FROM THE COUPLING END
LIST OF ROTATING ELEMENTS FOR REPLACEMENT
REF.NO. | DESCRIPTION | QTY. | MATERIAL/MAKE
1 | SHAFT | 1 | AISI 410
2 | IMPELLER | 1 | BRONZE LG2/DI
3 | CASE WEAR RINGS | 2 | BRONZE LB2
4 | IMPELLER WEAR RINGS | 2 | BRONZE LG2/DI
5 | SHAFT SLEEVES | 2 | BRONZE CT1
6 | SLEEVES NUTS (L.H & R.H) | 2+2 | BRONZE CT1
7 | DEEP GROOVE BEARINGS | 2 | SKF 6309
8 | BRG. LOCK NUT & WASHER | 1+1 | SKF KM09 & MB09
9 | WATER DEFLECTORS | 2SETS | NEOPRENE
10 | PACKING RINGS | 2 | GRAPHITED COTTON
11 | LOGGING RINGS | 2 | BRONZE LG2
12 | SPLIT GLANDS | 1 | BRONZE LG2
13 | IMPELLER KEY | 1 | AISI 410
14 | COUPLING KEY | 1 | AISI 410
STUFFING BOX FACE
STUFFING BOX FACE
VERT. CENTER LINE
PUMPSENSE FOR TATA STEEL
TITLE-
ROTATING ELEMENT ASSEMBLY
SCALE NTS
DRN PD 24.02.11
CHKD PD 24.02.11
APPD HS 24.02.11
DRG.NO. PSF/10UPH2-R/01
REV. 0
REV. DESCRIPTION DRN CHKD DATE