Pumps and Piping; Design, Performance and Commissioning Issues

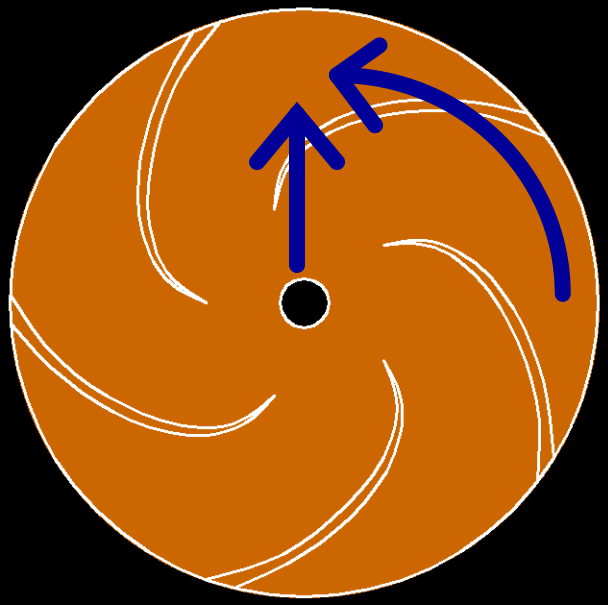
Pump Basics and Operating Theory

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering

Centrifugal Pump Operation

Centrifugal Pump Operation

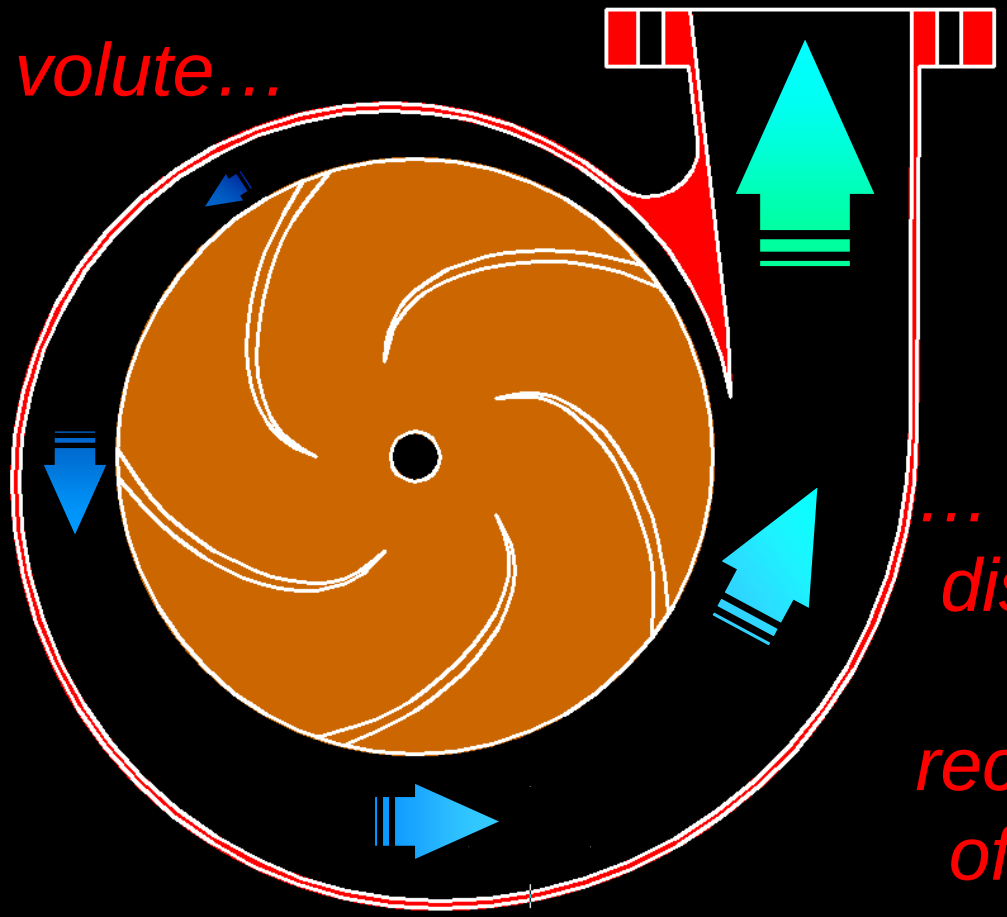
Spin the impeller …



… and water is thrown from the center to the perimeter

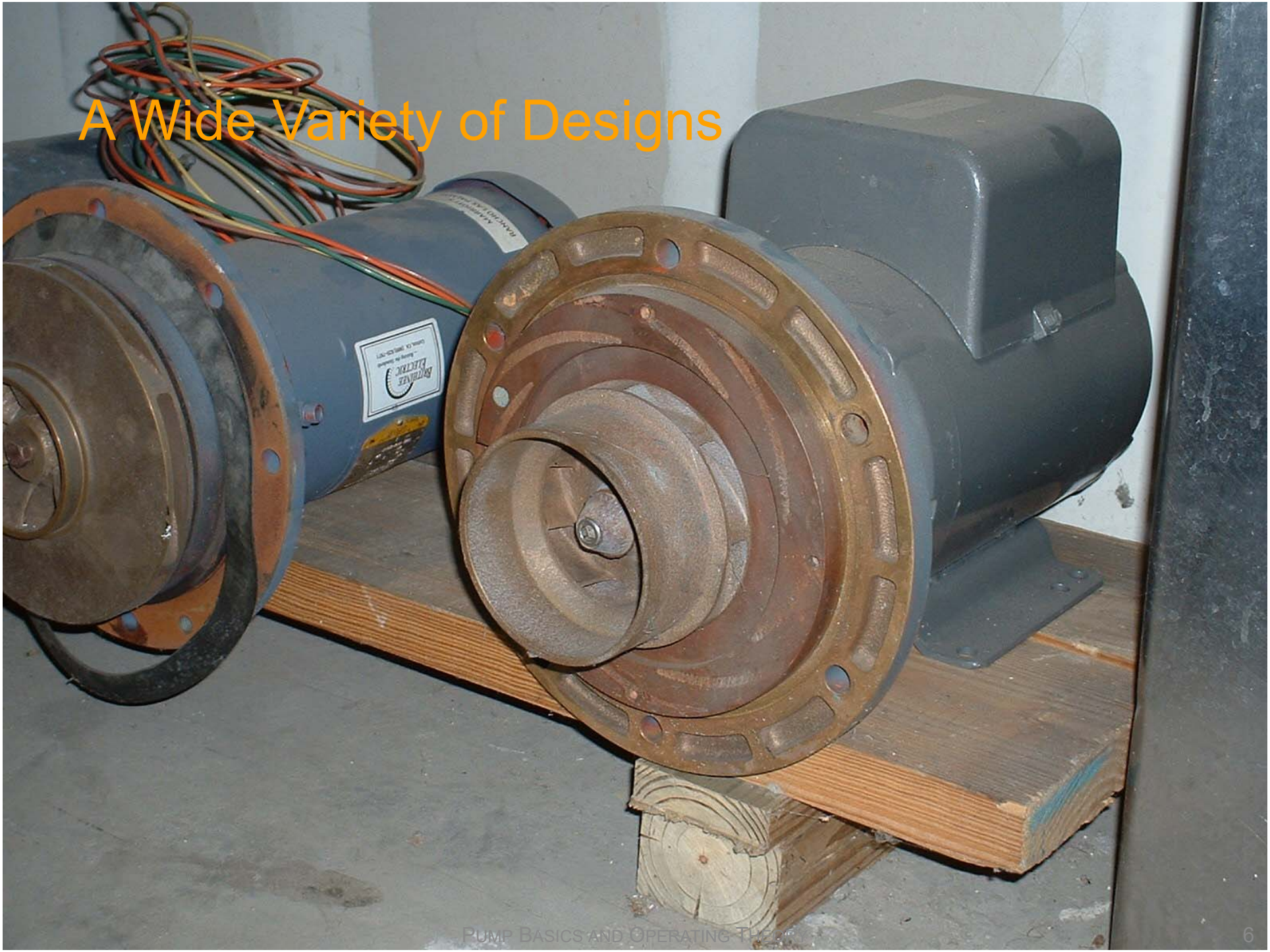
Centrifugal Pump Operation

Adding a volute…

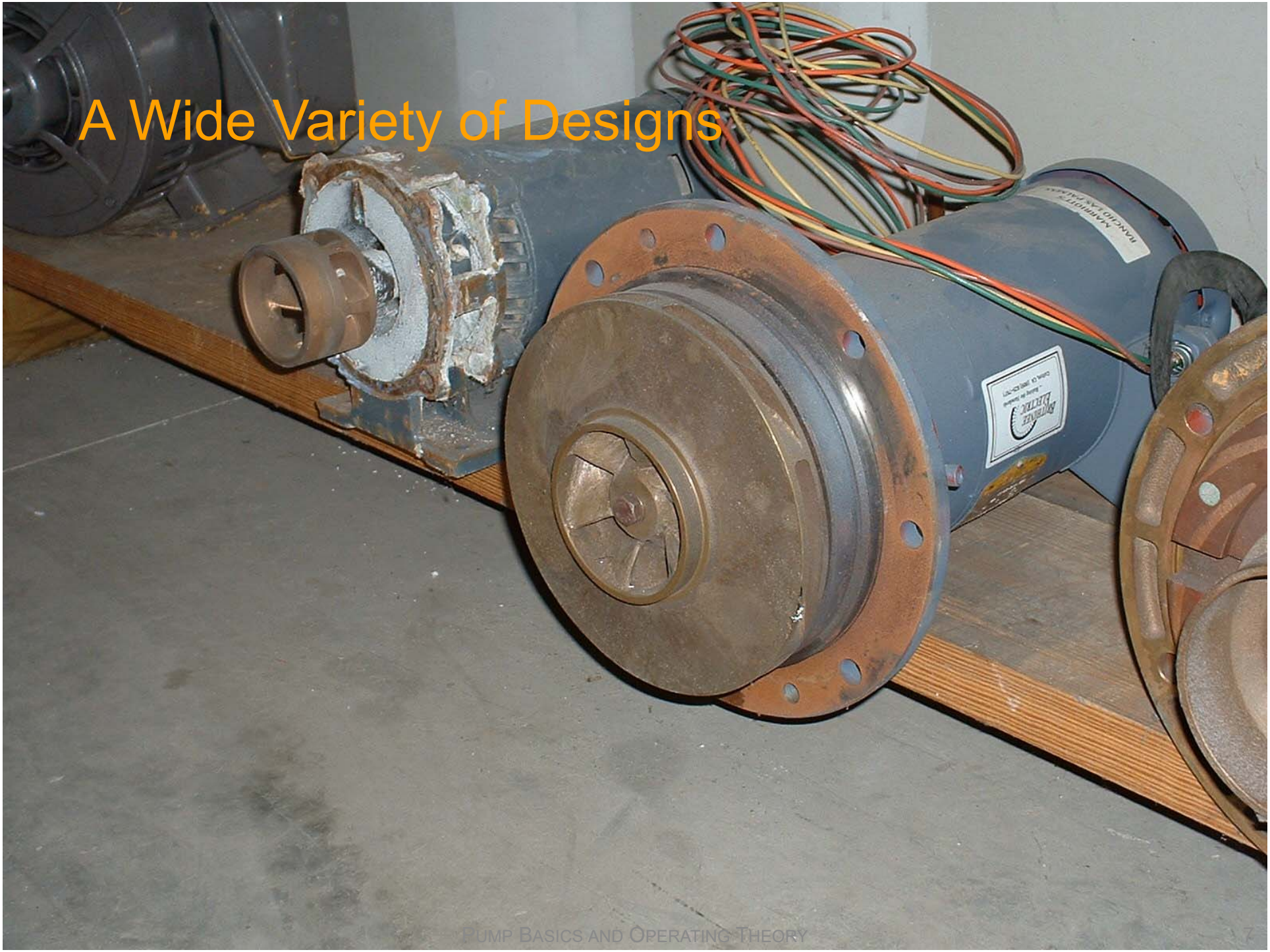


… collects and distributes the water and recovers some of the velocity pressure

A Wide Variety of Designs



A Wide Variety of Designs



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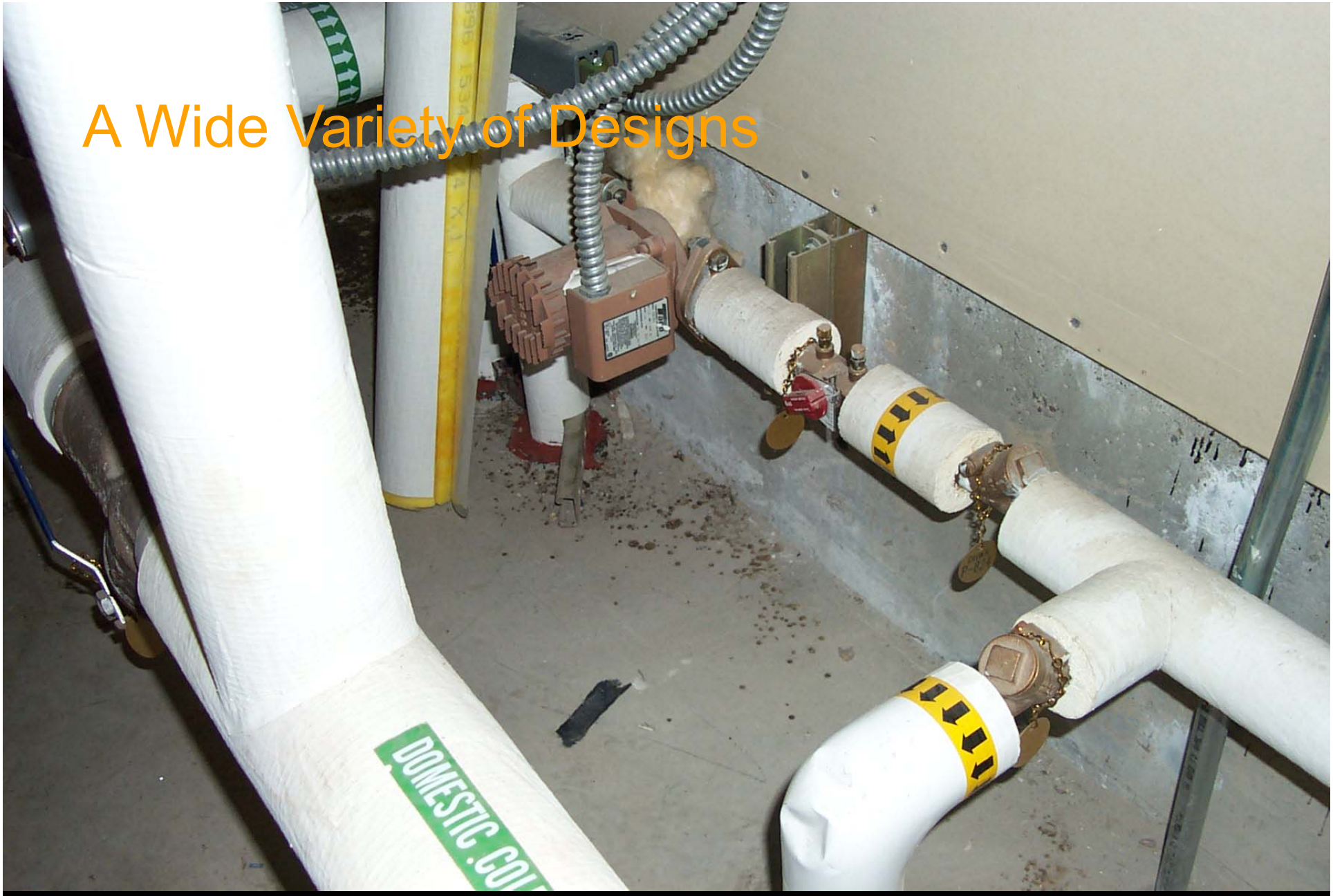

A Wide Variety of Designs

A Wide Variety of Designs

How Pumps are Put Together

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THELCO CUTAWAY DRAWING OF WORTHINGTON® PUMP MODEL D-1011 FRAME 2, 3, 4, AND 5 COOLING CAP SERIES ANSI PUMPS
MECHANICAL SEAL TYPE, SIZES; 2X1X10, 3X1-1/2X8, 3X1-1/2X10, 3X1-1/2X13, 3X2X8, 3X2X10, 3X2X13, 4X3X8, 4X3X10, 4X3X13, 6X4X8, 6X4X10, 6X4X11, 6X4X13, 8X6X11, 8X6X13, 8X6X15, 10X8X13, 10X8X15

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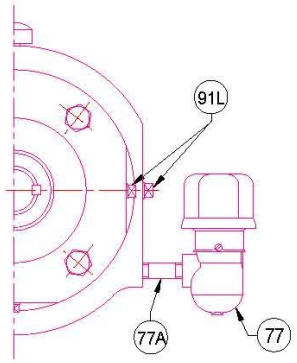
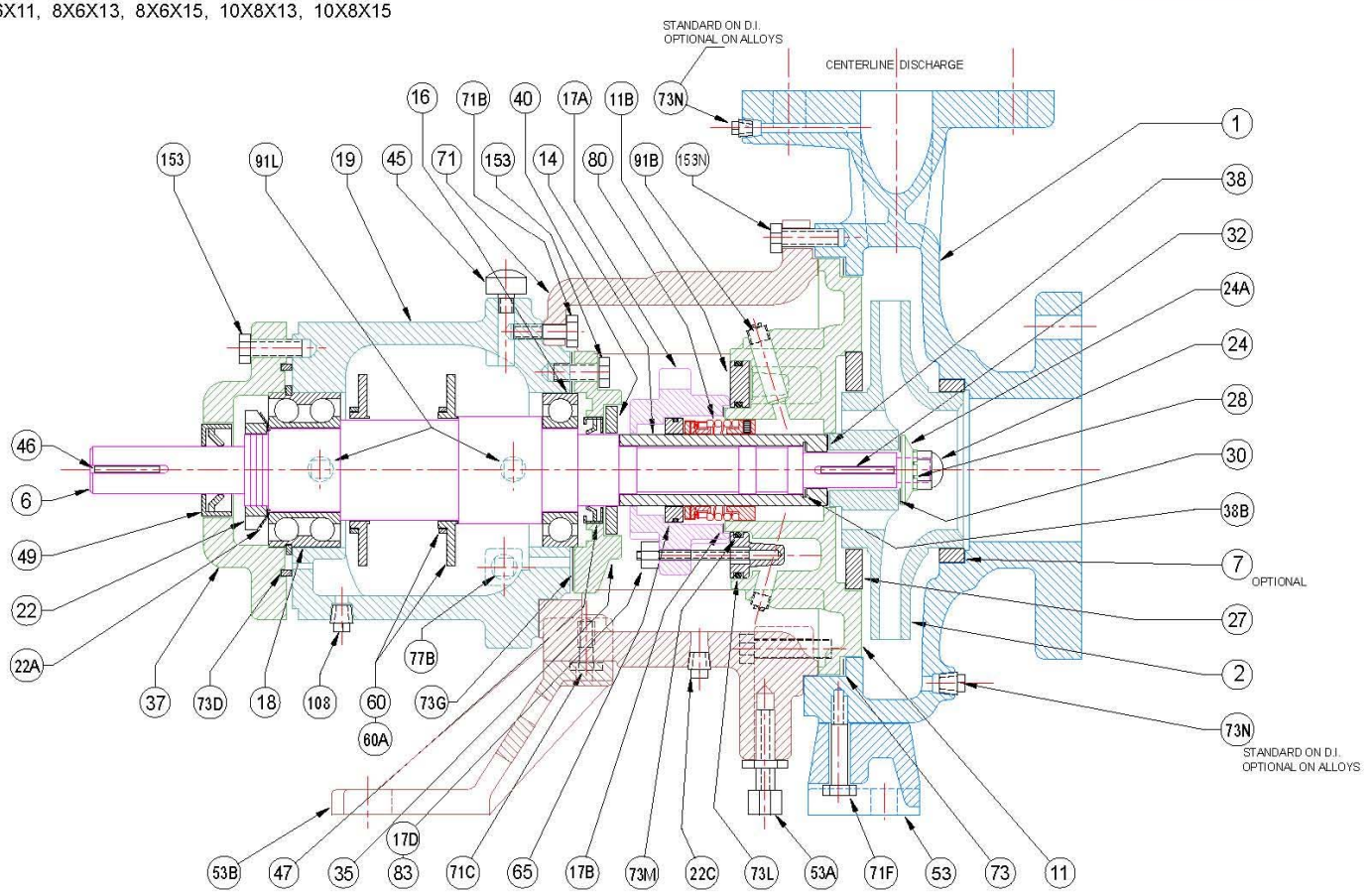
www.thelco.com





Note; Cut Shaft with Sleeve Version Shown.
Solid Shaft Version is Dimensionally Similar to Cut Shaft Including Sleeve.
Frm-1A Available in Cut Version Only.
*** These Two Parts are not Included with the Solid Shaft Version.

* Items contained in liquid end gasket kit.
** Items contained in frame end gasket kit

Nov 2008

REFERENCE NUMBERS

1	CASING	22C	PIPE PLUG	49	LIP SEAL, THRUST BEARING **	73L	O-RING, COOLING CAP (OUTER)
2	IMPELLER	24	NUT, IMPELLER	53	FOOT, CASING	73M	O-RING, COOLING CAP (INNER)
6	SHAFT (Shown Cut for a Sleeve)	24A	LOCK WASHER, IMPELLER *	53A	ADAPTER SUPPORT, INBOARD	73N	PIPE PLUG, CASING
7	RING, CASING (OPTIONAL)	27	RING, ADAPTER COVER	53B	ADAPTER SUPPORT	77	CONSTANT LEVEL OILER
11	STUFF BOX COVER	28	GASKET, IMPELLER NUT *	60	FLINGER, OIL	77A	NIPPLE, OILER
11B	COOLING CAP	30	GASKET, IMPELLER LOCK WSHR *	60A	COLLAR, OIL FLINGER	77B	PIPE PLUG, GREASE LUBE PUMPS
14	SLEEVE, SHAFT ***	32	KEY, IMPELLER	65	SEAT, MECHANICAL SEAL	80	ROTOR, MECHANICAL SEAL
16	LINE BEARING	35	COVER, LINE BEARING	71	ADAPTER	83	STUD, MECH SEAL GLAND
17A	GLAND, MECHANICAL SEAL	37	COVER, THRUST BEARING	71B	CAP SCREW, ADAPTER	91B	PIPE PLUG, STUFFING BOX
17B	GASKET, GLAND	38	GASKET, SLEEVE (OUTER) *	71C	CAP SCREW, ADAPTER FOOT	91L	PIPE PLUG, OIL LUBE PUMPS
17D	NUT, GLAND STUD	38B	GASKET, SLEEVE (INNER) * ***	71F	CAP SCREW, CASING FOOT	91L	GREASE FTG, GREASE LUBE PUMPS
18	THRUST BEARING	40	DEFLECTOR	73	GASKET, CASING *	108	PIPE PLUG, DRAIN
19	BEARING HOUSING	45	VENT CAP	73D	SEAL RING, THRUST BRG COVER **	153	CAP SCREW, BEARING COVER
22	LOCK NUT, BEARING	46	KEY, COUPLING	73G	GASKET, LINE BEARING COVER **	153N	CAP SCREW, CASING
22A	WASHER, BRG LOCK NUT **	47	LIP SEAL, LINE BEARING **				

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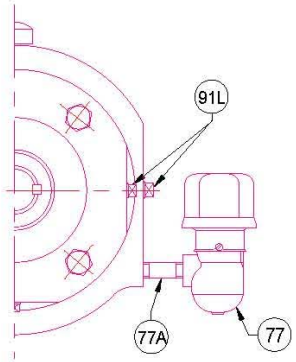

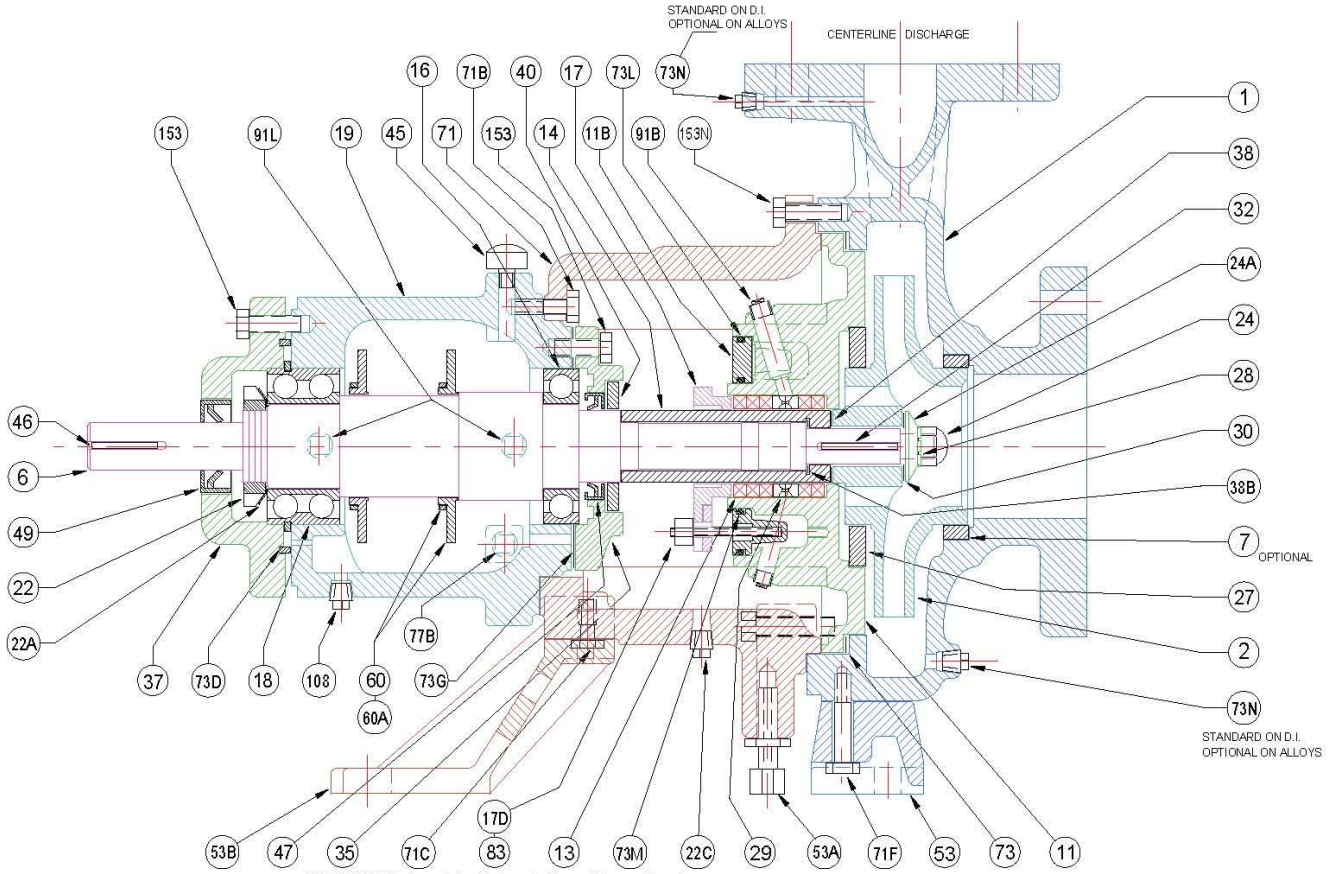

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** Items contained in frame end gasket kit

Nov 2008

REFERENCE NUMBERS

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2	IMPELLER	24	NUT, IMPELLER	47	LIP SEAL, LINE BEARING **	73L	O-RING, COOLING CAP (OUTER)
6	SHAFT (Shown Cut for a Sleeve)	24A	LOCK WASHER, IMPELLER *	49	LIP SEAL, THRUST BEARING **	73M	O-RING, COOLING CAP (INNER)
7	RING, CASING (OPTIONAL)	27	RING, ADAPTER COVER	53	FOOT, CASING	73N	PIPE PLUG, CASING
11	STUFF BOX COVER	28	GASKET, IMPELLER NUT *	53A	ADAPTER SUPPORT, INBOARD	77	CONSTANT LEVEL OILER
11B	COOLING CAP	29	SEAL CAGE SET	53B	ADAPTER SUPPORT	77A	NIPPLE, OILER
13	PACKING SET	30	GSKT, IMPELLER LOCK WSHR *	60	FLINGER, OIL	77B	PIPE PLUG, GREASE LUBE PUMPS
14	SLEEVE, SHAFT ***	32	KEY, IMPELLER	60A	COLLAR, OIL FLINGER	83	STUD, PACKING GLAND
16	LINE BEARING	35	COVER, LINE BEARING	71	ADAPTER	91B	PIPE PLUG, STUFF BOX
17	GLAND, PACKING	37	COVER, THRUST BEARING	71B	CAP SCREW, ADAPTER	91L	PIPE PLUG, OIL LUBE PUMPS
17D	NUT, GLAND STUD	38	GASKET, SLEEVE (OUTER) *	71C	CAP SCREW, ADAPTER FOOT	91L	GREASE FTG, GREASE LUBE PUMPS
18	THRUST BEARING	38B	GASKET, SLEEVE (INNER) * ***	71F	CAP SCREW, CASING FOOT	108	PIPE PLUG, DRAIN
19	BEARING HOUSING	40	DEFLECTOR	73	GASKET, CASING *	153	CAP SCREW, BEARING COVER
22	LOCK NUT, BEARING	45	VENT CAP	73D	SEAL RING, THRUST BRG COVER **	153N	CAP SCREW, CASING
22A	WASHER, BRG LOCK NUT **						

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THELCO CUTAWAY DRAWING OF WORTHINGTON®
SPLIT CASE PUMP MODEL LR .

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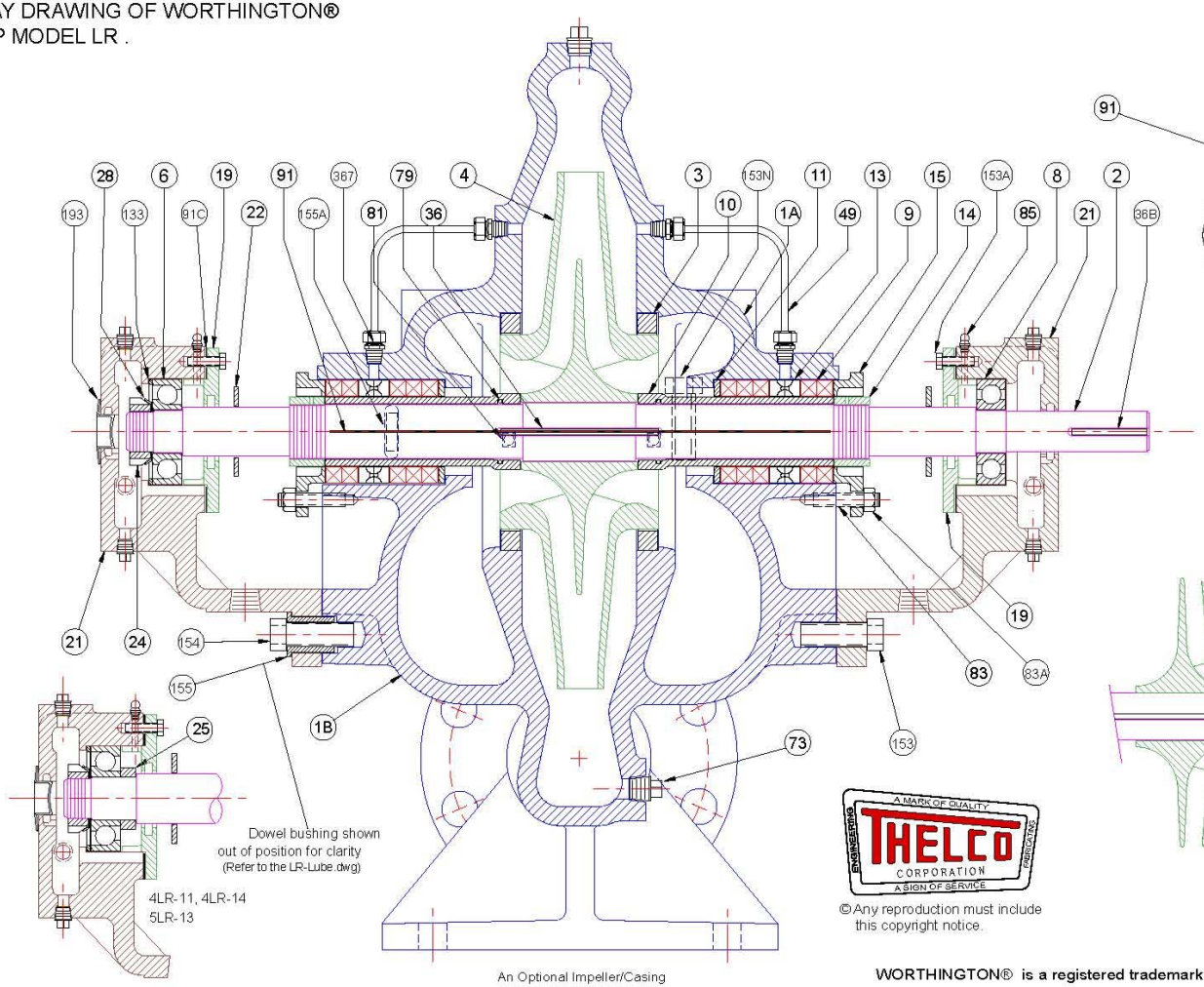
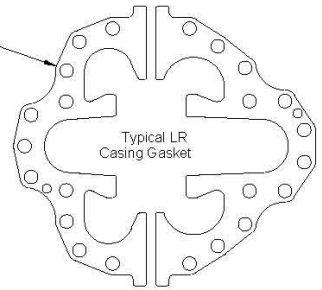
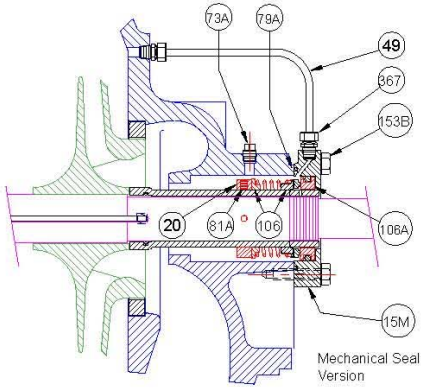
PUMP SIZES;
3LR-9
3LR-12
4LR-10
4LR-11
4LR-12
4LR-14
5LR-10
5LR-13
5LR-15
6LR-10
6LR-13
6LR-16
6LR-18
8LR-12
8LR-13
8LR-14
8LR-20
10LR-14
10LR-15
10LR-16

For 10LR-17, 10LR-18
Refer to Drawing LR-17-18







An Optional Impeller/Casing
Double Ring Repair Set Available.

REFERENCE NUMBERS

1A	Casing Upper Half	15	Gland, Packing	73	1/2 inch Pipe Plug	106A	Stationary Seat Mech Seal
1B	Casing Lower Half	15M	Gland, Mech Seal	73A	1/4 inch Pipe Plug	133	Bearing Shim
2	Shaft	19	Bearing Cover	79	O-Ring, Shaft Sleeve	153	Bearing Bracket Screws
3	Casing Ring	20	Mechanical Seal Collar	79A	O-Ring, Gland M. S.	153A	Bearing Cover Cap Screws
4	Impeller	21	Thrust/Line Brg Bracket	81	Set Screw, Casing Ring	153B	Cap Screw, M. S. Gland
6	Thrust Bearing	22	Deflector	81A	Set Screw, Collar M.S.	153N	Casing Split Cap Screws
8	Line Bearing	24	Bearing Lock Nut	83	Gland Stud	154	Dowel Bushing Screws
9	Packing	25	Bearing Spacer	83A	Gland Nut	155	Dowel Bushings
10	Shaft Sleeve	28	Bearing Lock Nut Washer	85	Grease Fitting 1/8 NPT	155A	Roll Pin
11	Stuffing Box Bushing *	36	Impeller Key	91	Casing Gasket	193	Dust Cover
13	Seal Cage	36B	Coupling Key	91C	Bearing Cover Gasket	367	Compression Fitting
14	Shaft Nut	49	Flush Tube, Optional	106	Rotating Element Mech Seal		

* Packed Box Only

How Pumps Use Energy

$$kW = \left(\frac{Flow \times Head}{3{,}960 \times \eta_{Pump} \times \eta_{Motor} \times \eta_{Drive}} \right) \times \frac{.746\ kw}{hp}$$

Where :

kW = Power into the motor and its drive system

$Flow$ = Flow rate in gallons per minute

$Head$ = Pump head in feet water column

$3{,}960$ = A units conversion constant

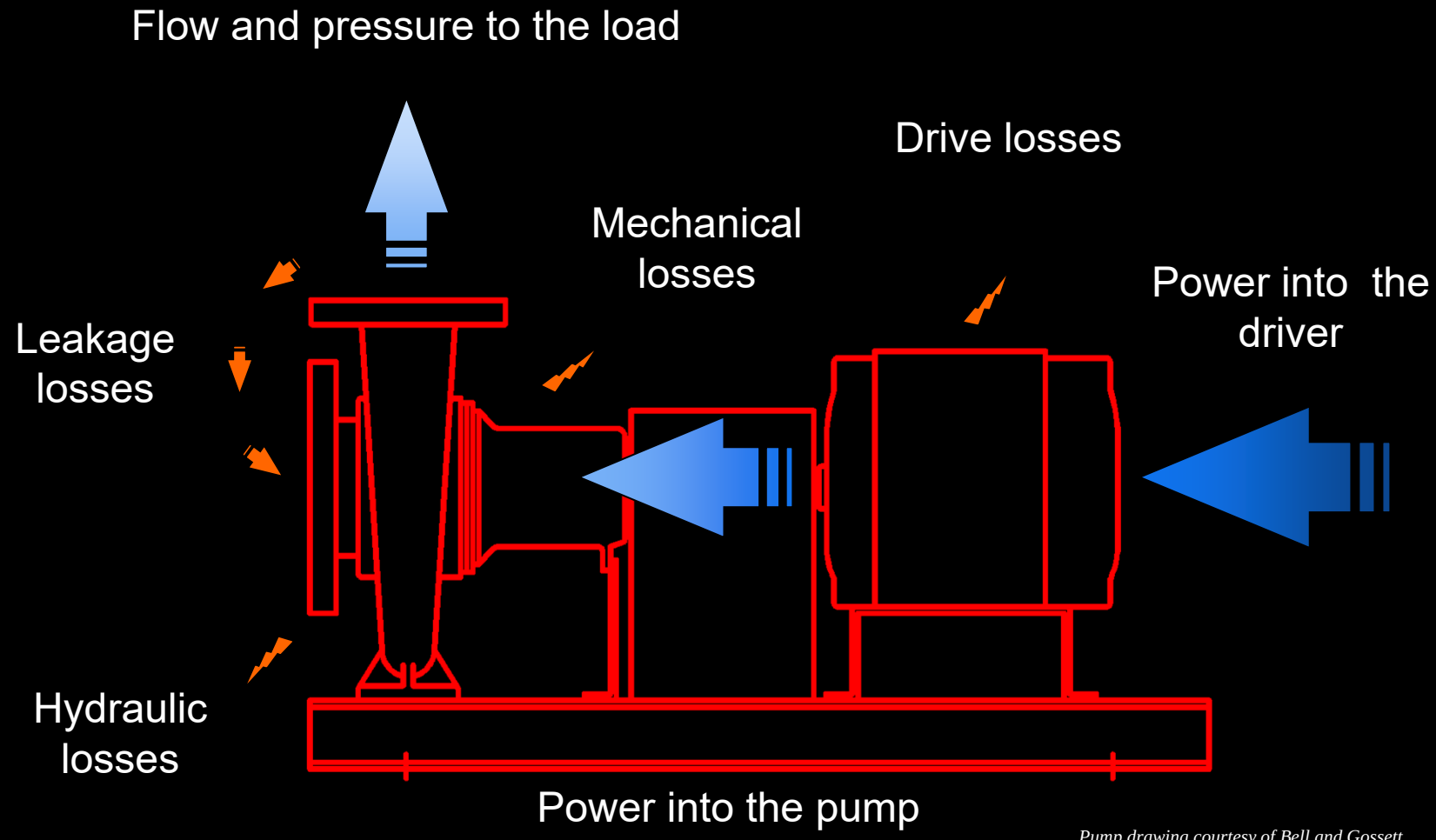
η_{Pump} = Pump efficiency

η_{Motor} = Motor efficiency

η_{Drive} = Drive efficiency

$\frac{.746\ kw}{hp}$ = kW to hp conversion constant

Pump Efficiency …



Pump drawing courtesy of Bell and Gossett

Drive System Losses

Energy conversion

- Electric motor efficiency
- Turbine efficiency

Bearings

Cooling fans

Aerodynamic effects

Pump Mechanical Losses

Can be minimized but not eliminated

- Bearing friction
- Packing drag
- Drag of water on the spinning impeller

Don’t vary much with the rate of discharge

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Wear Rings

THELCO CUTAWAY DRAWING OF WORTHINGTON® PUMP MODEL D-1011 FRAME 2, 3, 4, AND 5 COOLING CAP SERIES ANSI PUMPS
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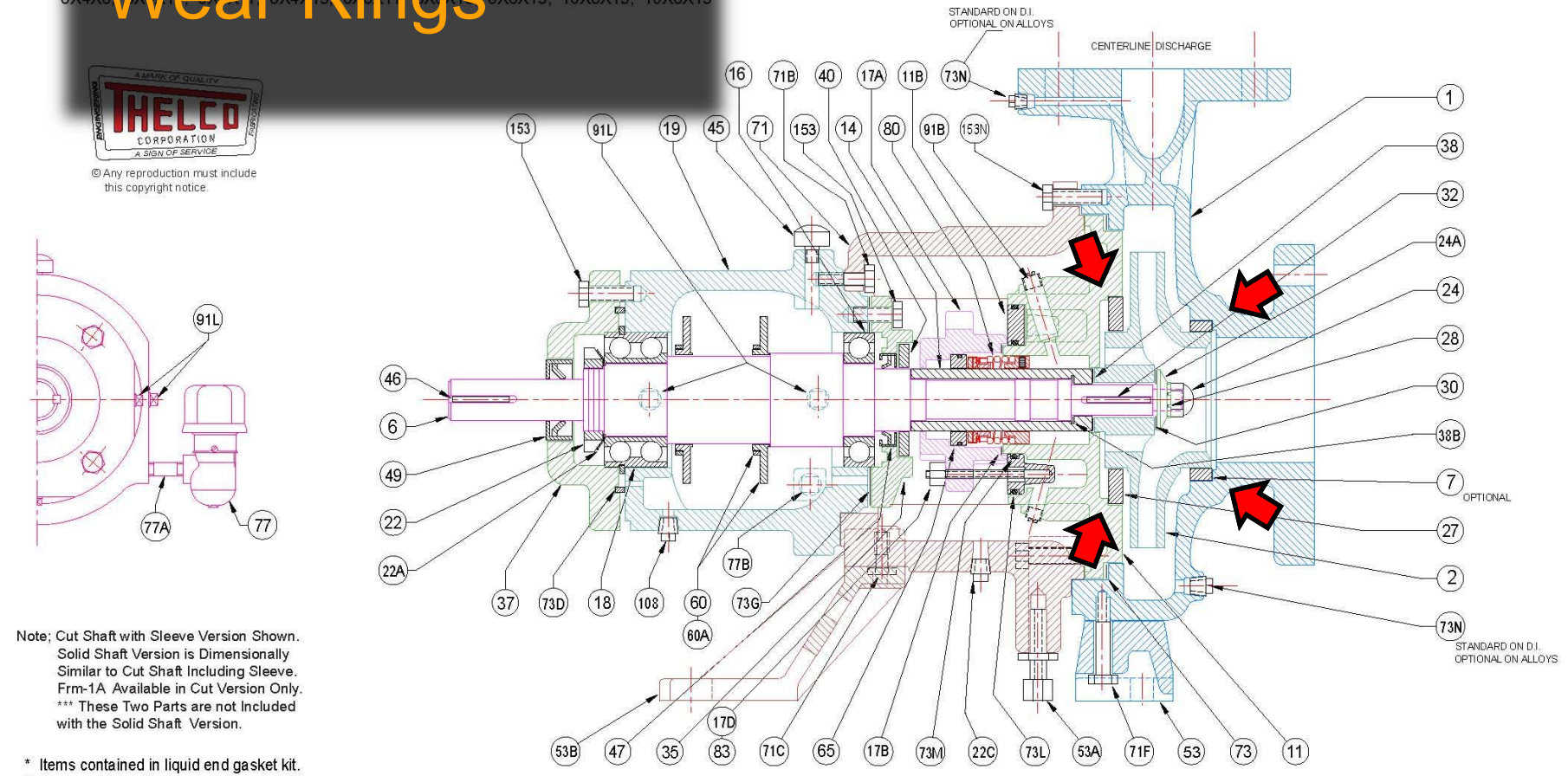

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Thelco is not affiliated with WORTHINGTON® or Ingersoll-Dresser Pump Company

Nov 2008

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22A	WASHER, BRG LOCK NUT **	47	LIP SEAL, LINE BEARING **				

Wear Rings – An O&M Consideration with Performance Implications

Different pump designs = Different leakage paths = Different wear ring designs

- Recessed vs. non-recessed
- Standard vs. optional
- Optional vs. none

Wear = increasing clearance

Increasing clearance = decreasing performance

Replaceable = renewable

Dead head test documents condition

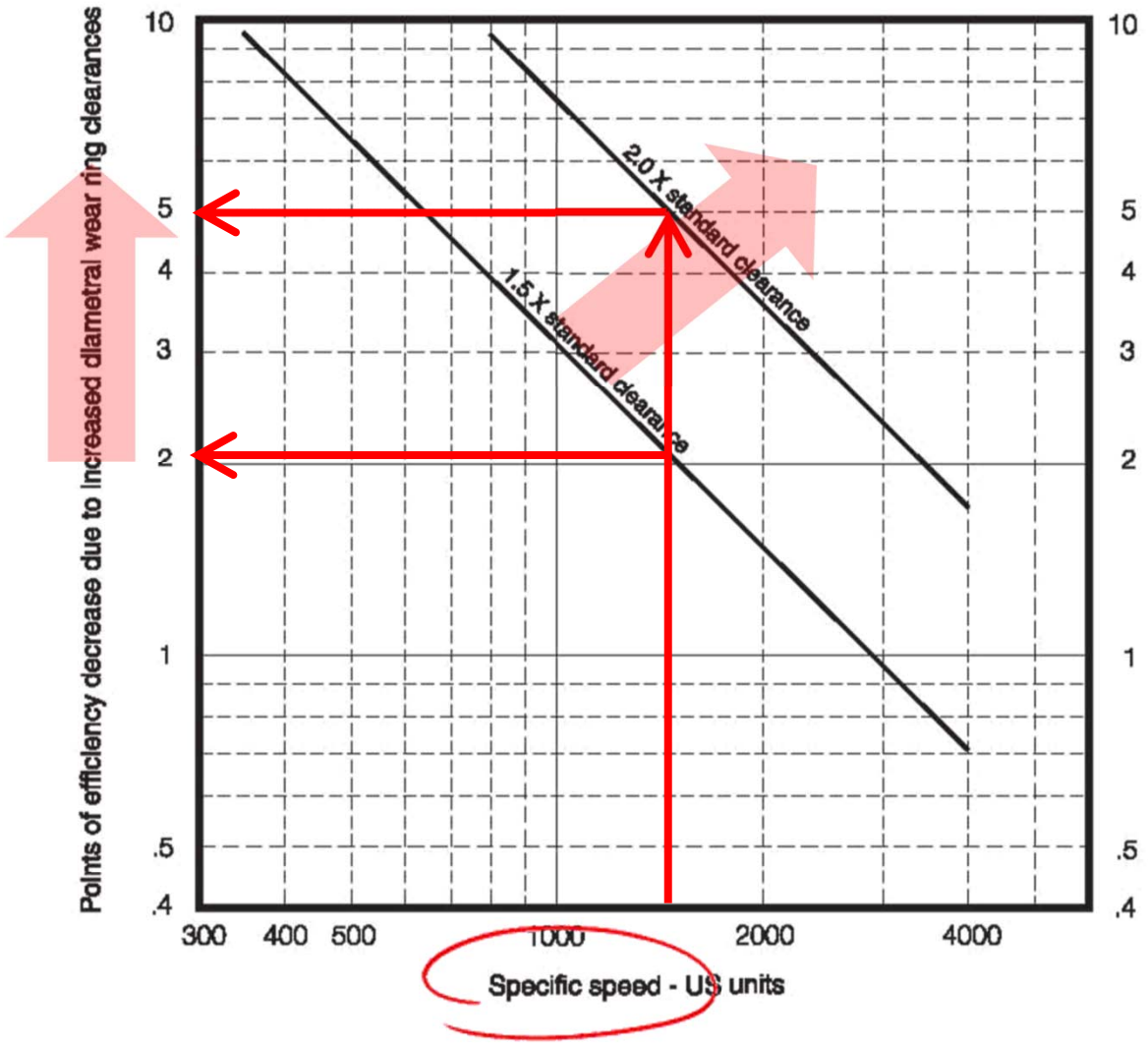


Figure 1.78B — Estimated efficiency decrease due to increased wear ring clearance (US Units)

Source – Hydraulic Institute

What's Specific Speed?

Number used by pump designers to compare pumps

> *The speed in revolutions per minute at which a geometrically similar impeller would operate if it were of such a size as to deliver one gallon per minute against one foot head.*

What's Specific Speed?

Number used by pump designers to compare pumps

$$N_s = \frac{N \times \sqrt{Q}}{H^{3/4}}$$

Where :

N = Pump speed in revolutions per minute

Q = Capacity in gallons per minute at the best efficiency point

H = Total head per stage at the best efficiency point

Specific Speed and HVAC Applications

Flow	Head	Specific Speed at Different Motor Speeds		
			1,750	
10	50		294	
50	50		658	
100	50		931	
1,000	50		2,943	
2,000	50		4,162	
4,000	50		5,886	

Tends to increase as flow increases

Specific Speed and HVAC Applications

Flow	Head	Specific Speed at Different Motor Speeds		
		1,150	1,750	3,500
10	50	193	294	589
50	50	432	658	1,316
100	50	612	931	1,861
1,000	50	1,934	2,943	5,886
2,000	50	2,735	4,162	8,324
4,000	50	3,868	5,886	11,773

Tends to increase as motor speed increases

Specific Speed and HVAC Applications

Flow	Head	Specific Speed at Different Motor Speeds		
		1,150	1,750	3,500
1,000	10	6,467	9,841	19,682
1,000	50	1,934	2,943	5,886
1,000	100	1,150	1,750	3,500

Tends to increase as head decreases

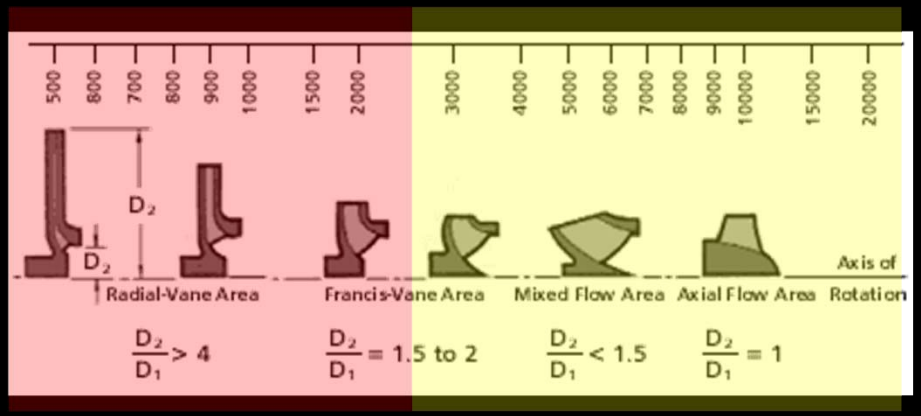
What's Specific Speed?

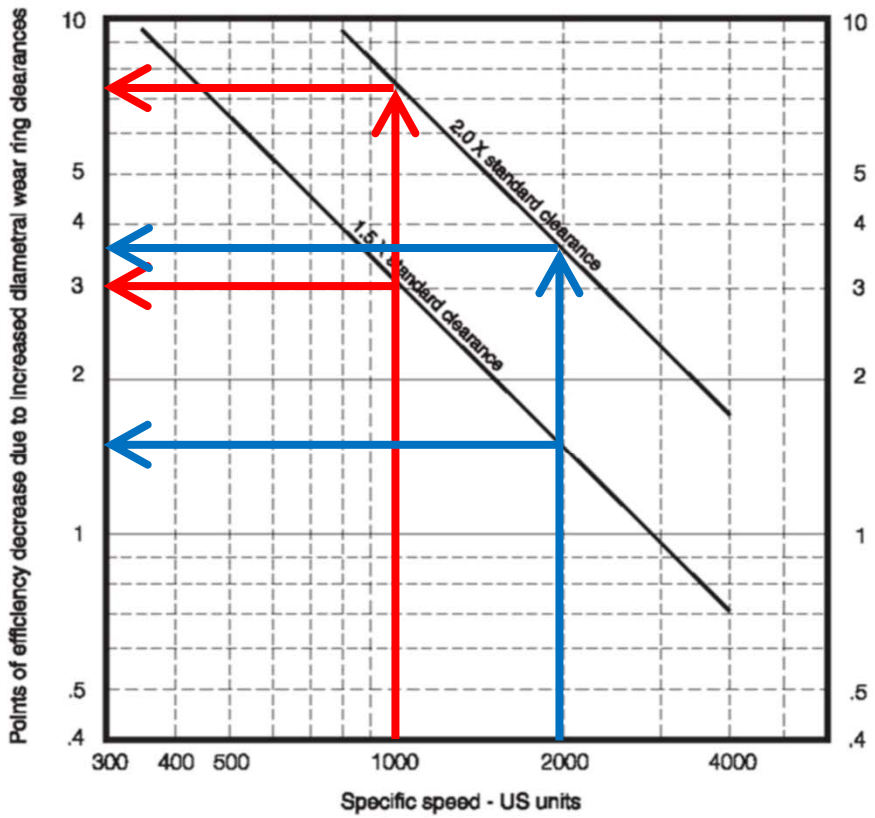
Low specific speed

- Head due to centrifugal and axial force
- Large impeller diameters
- High head, low flow

High specific speed

- Head primarily from axial force
- Small impeller diameters
- High flow, low head





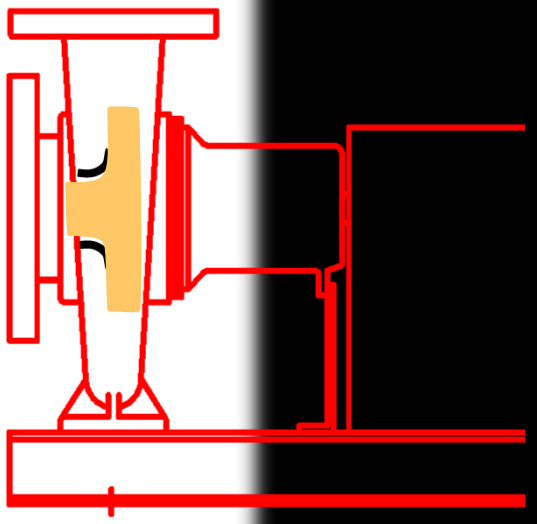


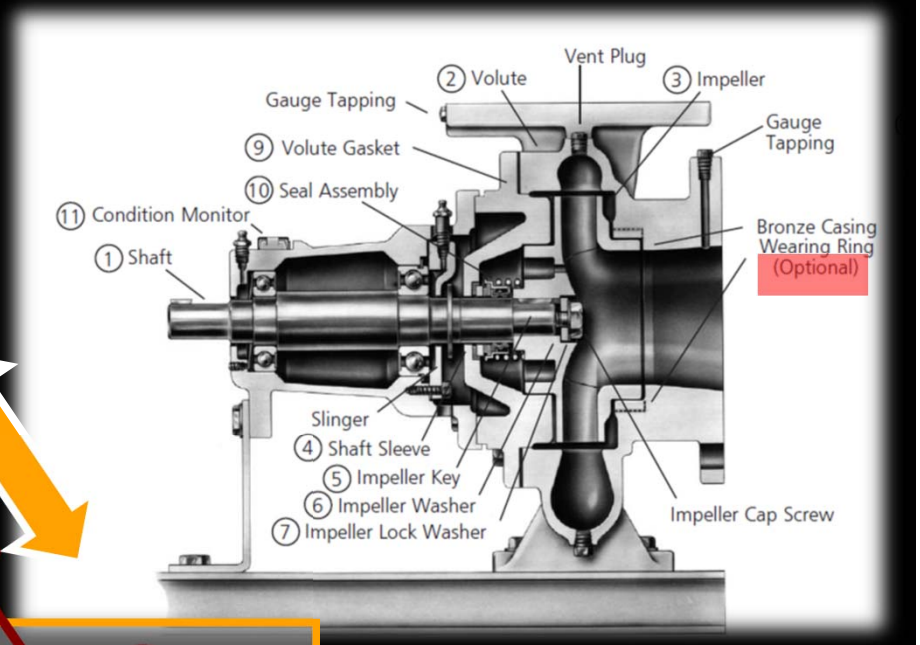
Figure 1.78B — Estimated efficiency decrease due to increased wear ring clearance (US Units)

Source – Hydraulic Institute

Operating Experience (On-going Cx)

Design Experience

Start-up and Cx Experience



Source - Bell and Gossett Electronic Catalog

Specify “optional” wear rings!

… and verify the requirement in review cycles

Perform a shut off test to document minimum wear condition …

… and repeat the test as a preventive maintenance procedure

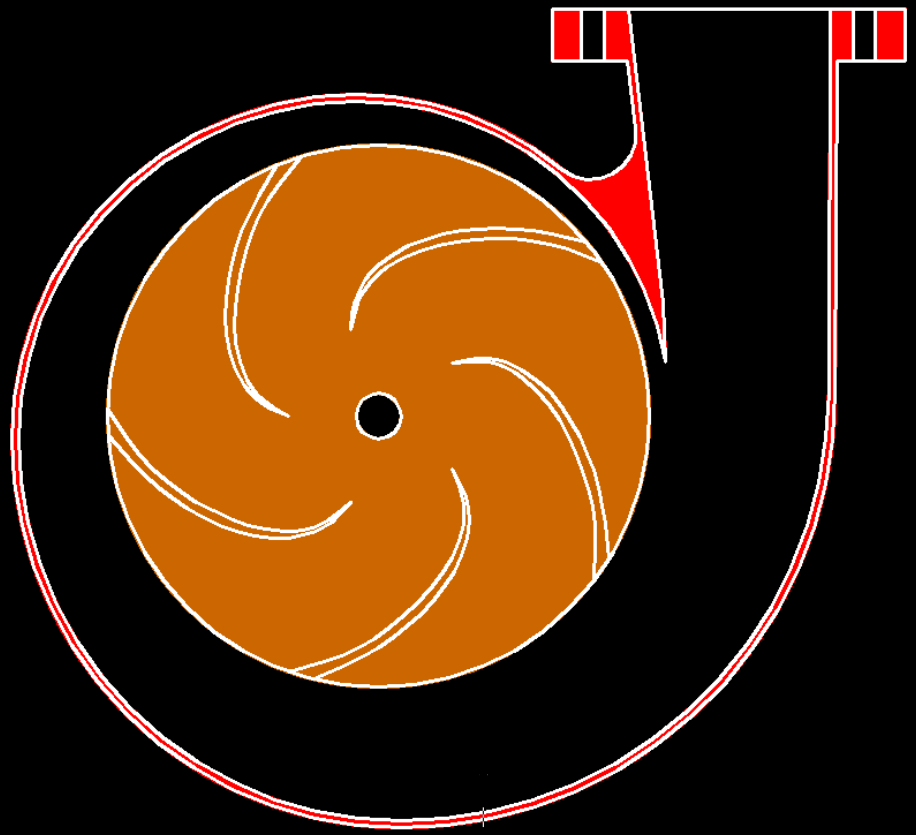
Hydraulic losses

Associated with accelerating the pumped fluid into the eye of the impeller and then decelerating it into the volute

- Complex velocity conversions
- Optimized for a particular flow rate
- Impacts bearing and shaft loads

Churn

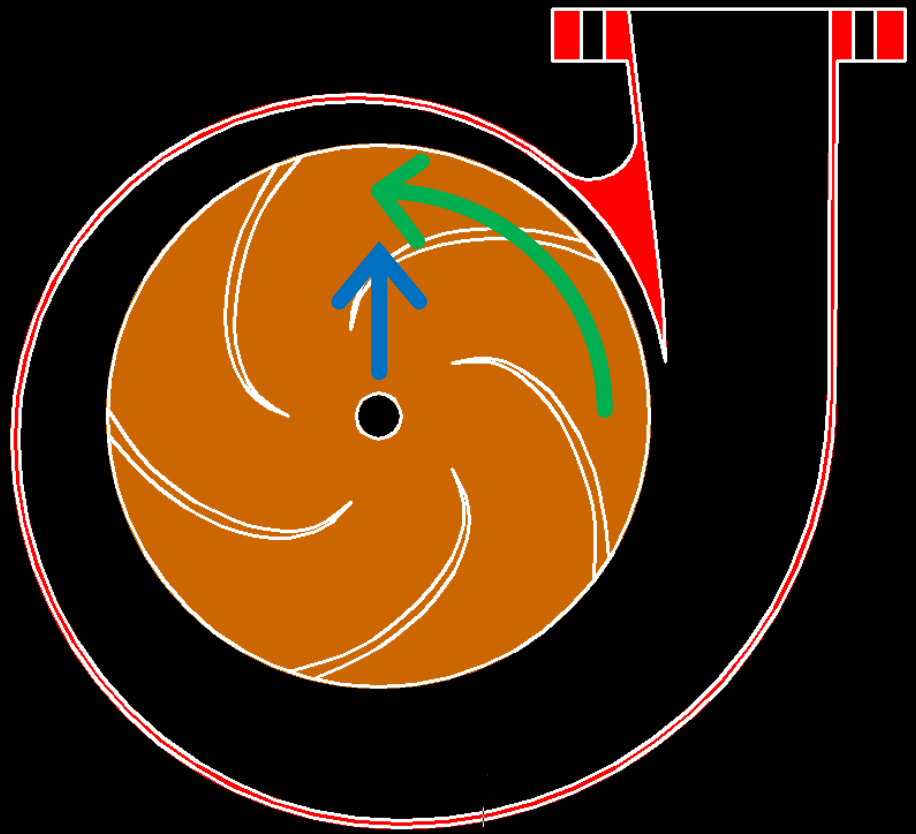
- Eddies in the volute
- Low flow phenomenon



Hydraulic losses

Water entering the impeller experiences:

- Radial acceleration
- Angular acceleration



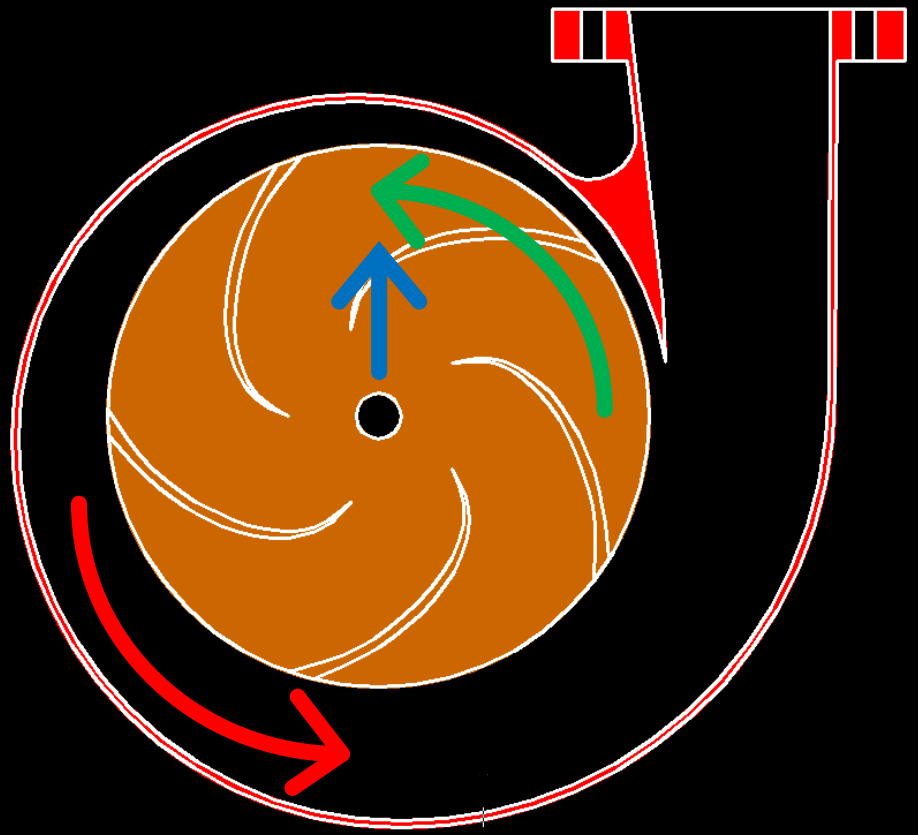
Hydraulic losses

Water entering the impeller experiences:

- Radial acceleration
- Angular acceleration

Upon exiting the impeller:

- It merges into a rotating velocity field
- Looses radial acceleration



Hydraulic losses

Water entering the impeller experiences:

- Radial acceleration
- Angular acceleration

Upon exiting the impeller:

- It merges into a rotating velocity field
- Looses acceleration
- Increasing volume/mass as the water flows towards the outlet of the volute puts non-uniform loads on the shaft and bearings