KEY TO PUMP SELECTION

♤NORMAL VARIABLES IN PUMP SELECTION

→LOCATION

→FUNCTION

→TYPE OF HYDRAULIC SERVICE

♤FLUID CHARACTERISTICS

→CHEMICAL IDENTITY OF THE FLUID

→ABSOLUTE VISCOSITY AT PT AND 60℉(CENTIPOISES)

;KINEMATIC VISCOSITY (CENTISTOKES)

;SAYBOLT SECONDS UNIVERSAL (SSU)

→SPECIFIC GRAVITY OF THE FLUID AT PT AND 60℉

→PUMPING TEMPERATURE AND VAPOR PRESSURE AT PT

→PERSONALITY OF THE FLUID

♤HYDROLICS OF THE SYSTEM(첨부 1:pump & line calculation sheet 참조)

→PRESSURE

;BAROMETRIC,GAUGE,ABSOLUTE PRESSURE

→HEAD

;HEAD FT =2.31 X PRESSURE(PSI) / SP GR

→STATIC HEAD

→VELOCITY HEAD

;KINETIC ENERGY OF A FLOWING FLUID = $V^2/2G$

→SUCTION LIFT

;MANOMETER READING AT THE PUMP SUCTION MINUS THE VELOCITY HEAD

→TOTAL DISCHARGE HEAD

→TOTAL HEAD

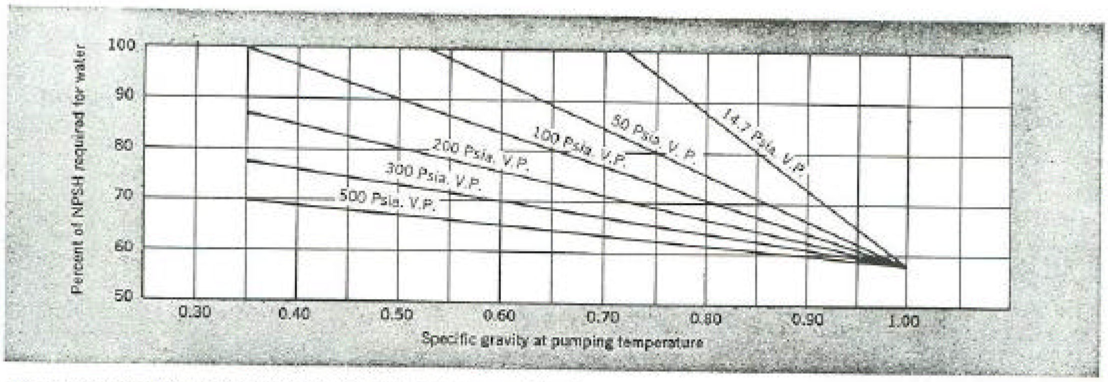
→HEAD LOSSES

→NPSH

;CAVITATION EVIDENT ..INCREASED NOISE,LOSS OF DISCHARGE HEAD,REDUCED FLUID FLOW

♤CALCULATING NPSH

→NPSH CORRECTION FACTORS FOR PUMPING HYDROCARBONS



NPSH CORRECTION factors for pumping hydrocarbons—Fig. 1

;WATER 은 다른 HYDROCARBON과 비교해서 일정 온도에서 VAPOR PRESSURE 가 작다

;WATER BASED NPSHR > HYDROCARBON BASED NPSHR

Vp ↑ NPSH reduction↑ NPSH required↓

CORRECTED NPSH required = NPSH required at WATER - NPSH reduction

NPSH reduction >1/2 NPSH required at WATER → CORRECTED NPSH required=1/2 NPSH required at WATER

NPSH reduction <1/2 NPSH required at WATER → CORRECTED NPSH required=NPSH required at WATER – NPSH reduction

;NPSHR 은 PUMP 의 IMPELLER내에서 일어나는 PRESSURE DROP 이다

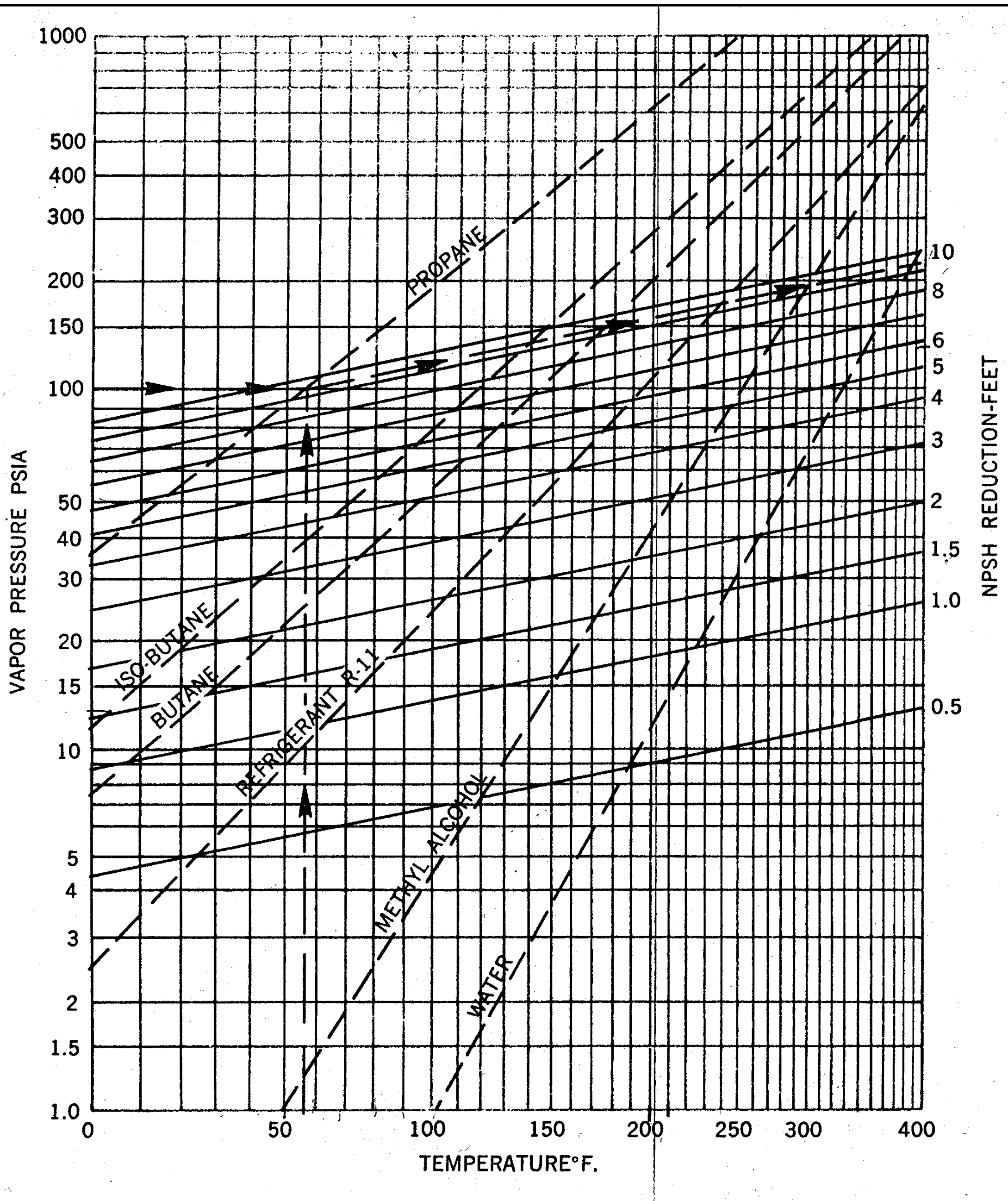


Fig. 70 NPSH REDUCTION FOR PUMPS HANDLING HYDROCARBON LIQUIDS AND HIGH TEMPERATURE WATER

Note: This chart has been constructed from test data obtained using the liquids shown. For applicability to other liquids refer to the text.

→POSITIVE SUCTION 기준

;**TOTAL HEAD** = (DIS GAUGE HEAD+DIS VELOCITY HEAD) - (SUC GAUGE HEAD+SUC VELOCITY HEAD)

;**TOTAL SUC HEAD** = SUC STATIC HEAD + SUC SURFACE PRESS HEAD – SUC FRICTION HEAD LOSS = (DIS GAUGE HEAD+DIS VELOCITY HEAD)

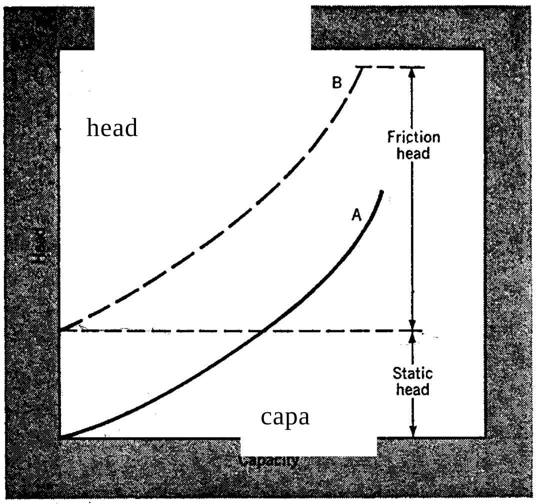
;**TOTAL DIS HEAD** = DIS STATIC HEAD + DIS SURFACE PRESS HEAD + DIS FRICTION HEAD LOSS = (SUC GAUGE HEAD+SUC VELOCITY HEAD)

;**NET POSITIVE SUC HEAD** = TOTAL SUC HEAD ABSOLUTE - VAPOR PRESSURE ABSOLUTE

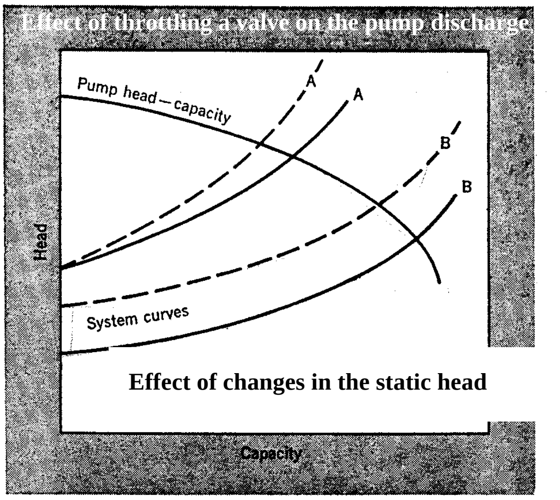
♤ACCELERATION HEAD

;REQUIRED TO ACCELERATE THE FLUID IN THE SUCTION LINE

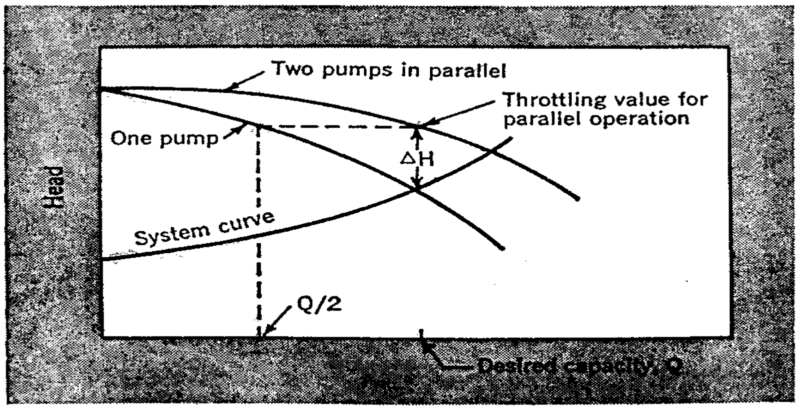
→**NPSH** = hp – hvpa ± hst – hfs – ha



SYSTEM HEAD curves for a typical application—Fig. 2



EFFECT of changes in the hydraulic system—Fig. 3



THROTTLING with parallel pumps—Fig. 4

→pump 의 운전점
(단독운전)
첨부 3 참조

♤SPECIAL PROBLEMS

CENTRIFUGAL PUMPS	BELOW 5% ENTRAINED GAS
REGENERATIVE TURBINE PUMPS	50% ENTRAINED GAS
RECIPROCATING OR ROTARY PUMPS	VIRTUALLY NO LIMIT

→VISCOUS FLUIDS ; REDUCE EFFICIENCY AND INCREASE HP REQUIREMENT

→CORRECTION FACTORS ARE AVAILABLE TO PREDICT PERFORMANCE AT VARIOUS

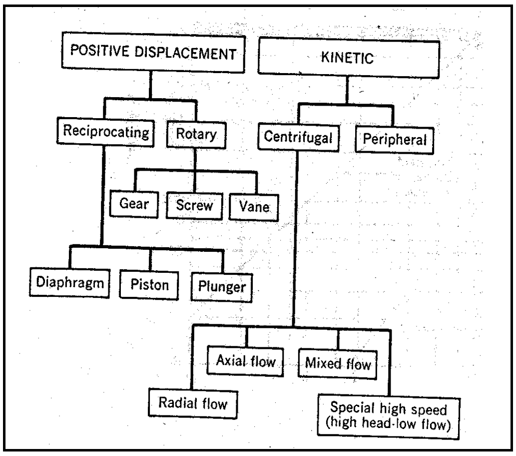
VISCOSITIES(첨부 4 참조)

→SLURRIES (SOLID/LIQUID MIXTURES)

;PUMP 에 의해 SOLID 에 IMPART 된 ENERGY 는 PRESSURE ENERGY 로 전환되지못한다. 그래서 PUMP EFFICIENCY 에 감소를 가지고 온다

;CENTRIFUGAL PUMP ,OTHER THAN REGENERATIVE TURBINE TYPES, ARE BEST SUITED FOR SLURRIES AND MIXTURES WITH OVER 50% BY WEIGHT

♤STEPS IN PUMP SELECTION



→FIRST STEP

;ANALYZE THE PUMP' S FUNCTION AND INSTALLATION,AND DEVELOP SYSTEM CHARACTERISTICS

→NORMAL CENTRIFUGAL CAPABILITIES 영역에서 500SSU 이상이거나 5% ENTRAINED GAS 이면 POSITIVE DISPLACEMENT PUMP 가 적합하다

→CENTRIFUGAL PUMP 가 SLURRIES 를 HANDLING 할 때는 SPEED 가 1800RPM 보다 작거나 같하야 한다

→SOLID VOLUME 이 3 TO 5%이면 SPECIAL SLURRY PUMP 가 필요

→SPECIFIC SPEED

;HIGHER SPEED PUMP 가 더 경제적

→HORIZONTAL PUMP 는 12 TO 14 STAGES 가 PRACTICAL LIMIT

→VERTICAL PUMP

;LIFT STATION,SUMP,INHERENT MIXED OR AXIAL FLOW

;IMPELLER를 요구되는 깊이만큼 SUBMERGING 함으로서 적절한 NPSH 를 얻기위해 사용

;UNUSUAL HIGH HEAD 가 필요한곳

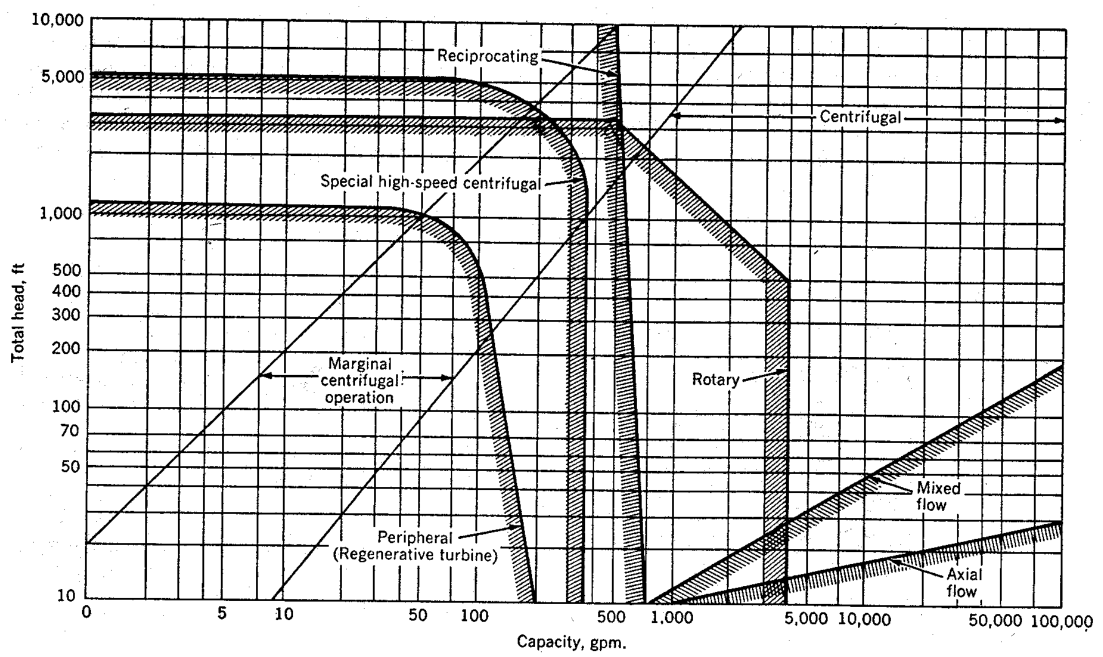
→LIGHTER – DUTY CHEMICAL PUMP OR API STD FOR REFINERY SERVICE

;API 가 2 ~3 배 비싸다

; LIGHTER – DUTY CHEMICAL PUMP 는 규격화 돼있다

1.API PUMP 및 ASME B73.1 (ANSI) PUMP 적용기준 비교표

DESCRIPTION	A P I	ASME B73.1 (ANSI)
1. Max. disch. press.	Over 275 psig	Below 275 psig
2. Max. pumping temp.	Over 150 ℃	Below 150 ℃
3. Rated total head	Over 120 meter	Below 120 meter
4. Flange rating	Over 300 #	150 #
5. Casing mounting	Centerline mount	Foot mount
6. Pump speed	-	Max. 3600 rpm
7. Application	1. H/C 공정지역 모두 해당됨 2.연속운전 Service 3.상기운전 조건 모든 Service	1.화학공정 지역중 * Low pressure * Low temperature * Low flow 상기 운전 조건 2.Off-site 지역 3.비연속 운전 Service



♤MATERIALS OF CONSTRUCTION

DUCTILE IRON	CAST IRON보다 비싸지만 CHEMICAL PUMP 의 STD
CAST STEEL	CAST IRON보다 2 TO 2.5배 비싸고 REFINERY OR HIGH P SERVICE 에 적합 PRODUCT가 FLAMMABLE OR TOXIC 불타는 동안 물이 뿌려져도 쉽게 안 깨진다
CAST IRON	GOOD CORROSION RESISTENCE TO MILD CAUSTIC AND COLD NON-CORROSIVE SOLUTION
CHROME & CHROME-NICKEL ALLOY STEEL	ACID SOLUTION에 사용 HIGH T, CORROSION, EROSION 이 문제가 될 때 사용
BRONZE	상동이나 MILD T일때 사용
NICKEL-BASE ALLOYS	CONCENTRATED, HOT, CAUSTIC SOLUTIONS OR FLUIDS WITH HIGH CHLORIDE CONTENTS

→CENTRIFUGAL PUMP IMPELLER 에는 TOUGHER MATERIAL사용

→WEAR RINGS

CAST IRON AGAINST CAST IRON	50SSU AND ABOVE
CAST IRON OR BRONZE RING AGAINST CHROME STAINLESS STEEL	LESS VISCOUS LIQUID

♤ROTARY DESIGN(GEAR,SCREW, VANE 등)

→ADVANTAGE

;LOW NPSH REQUIREMENT

;PRODUCE HIGH SUCTION LIFTS

;VISCOUS LIQUID 를 PUMPING 할때 상대적으로 높은 EFFICIENCY

;HIGH HEADS AT A WIDE RANGE OF CAPAVITIES

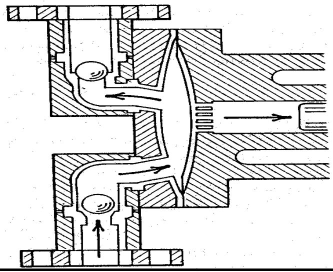
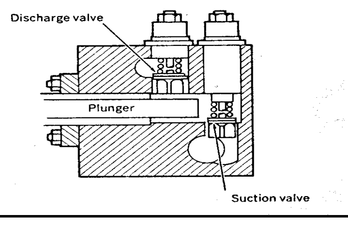
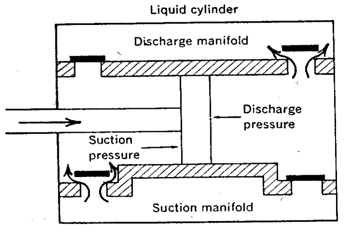
;EXTENSIVE SPEED RANGE,GENERALLY LIMITED ONLY BY THE FLUID'S VISCOSITY

;SELF PRIMING

;COMPRESSOR 처럼도 작동(29IN Hg 를 PRODUCE 할수 있다)

VANE	DIFFERENTIAL P 50PSI CAPA 375GPM LIQUID VISCOSITY LIMIT 는 100,000SSU LIQUID 가 POOR LUBRICATING QUALITIES 하면 사용할수 없다
GEAR	650GPM 350PSI 5MILLION SSU 에 이르는 VISCOSITIES 도 HANDLING 할수 있다
상기 두 PUMP 는 PUMPING LIQUID 가 100 TO 500SSU 일때 TOP SPEED 가 1,200RPM	
SCREW	4000GPM 3000PSI 100MILLION SSU OPERATE AT HIGHER SPEEDS BECAUSE OF RELATIVELY LOWER FLUID VELOCITIES

♤RECIPROCATING PUMP CAPABILITIES

DIAPHRAGM TYPE	CONTROLLED VOLUME APPLICATIONS 600GAL/HR 3500PSI FOR SIMPLEX UNITS	
PLUNGER PUMPS	METERING 에 사용도 됨 1000GAL/HR 7500PSI	
PISTON PUMPS	MAXIMUM PERFORMANCE 는 600GPM 750PSI PLUNGER TYPE 보다 싸다 SHORTER SERVICE LIFE	

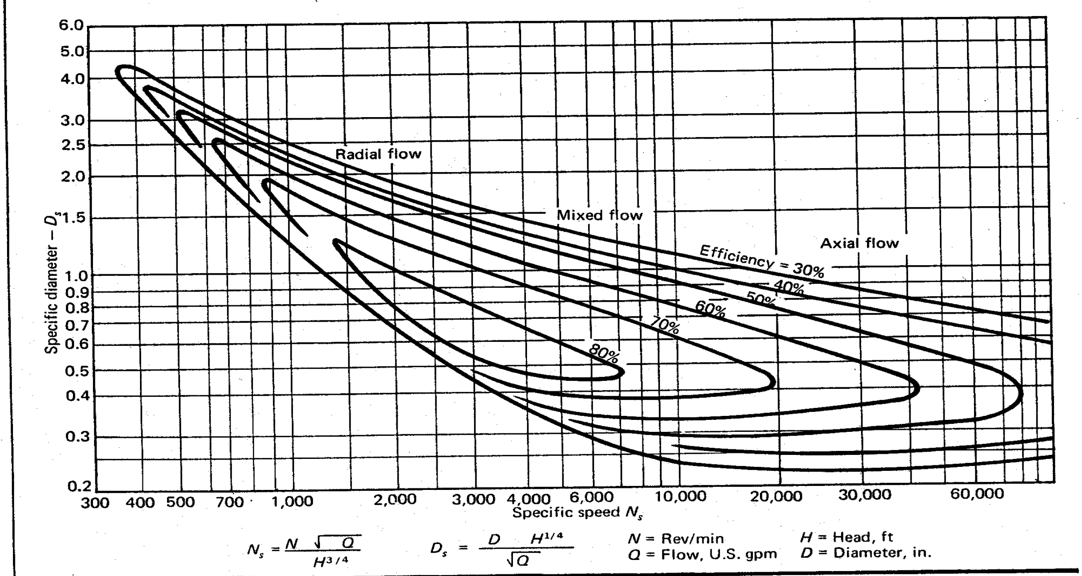
→PULSATION IS INHERENT 하므로 DAMPENER 나 MULTIPLE ENDS 의 배열로서 감소시킴

SELECTING THE RIGHT PUMP

♤SPECIFIC SPEED AS A GUIDE

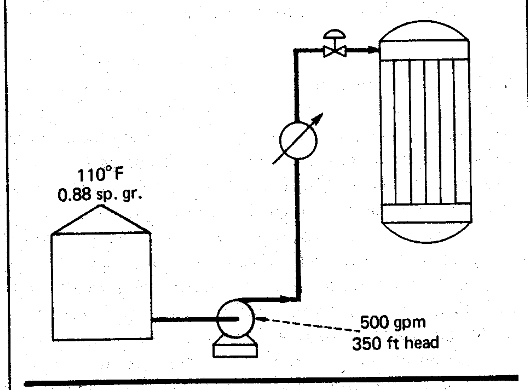
$Ns = (N \sqrt{Q}) / H^{3/4}$

→ THIS HELPS IN RATING ALL CENTRIFUGAL PUMPS



Specific-speed chart is of great use in the preliminary selection of single-speed centrifugal pumps Fig. 1

♤SELECTION FOR BEST EFFICIENCY



Flow sketch of simple system analyzed in text Fig. 2

→TYPICAL FEED PUMP
;ATM, CLEAN LIQUID , NON-VOLATILE OR TOXIC , AMPLE NPSH , NO SOLID , VICOSITY ABOUT LIKE WATER

→Ns 를 구해서 ESTIMATED EFFICIENCY 를 구하고 Ds 를 찾는다.Ds 를 가지고 D 값을 알 수 있다(상기표의 공식에서):TABLE 1 참조

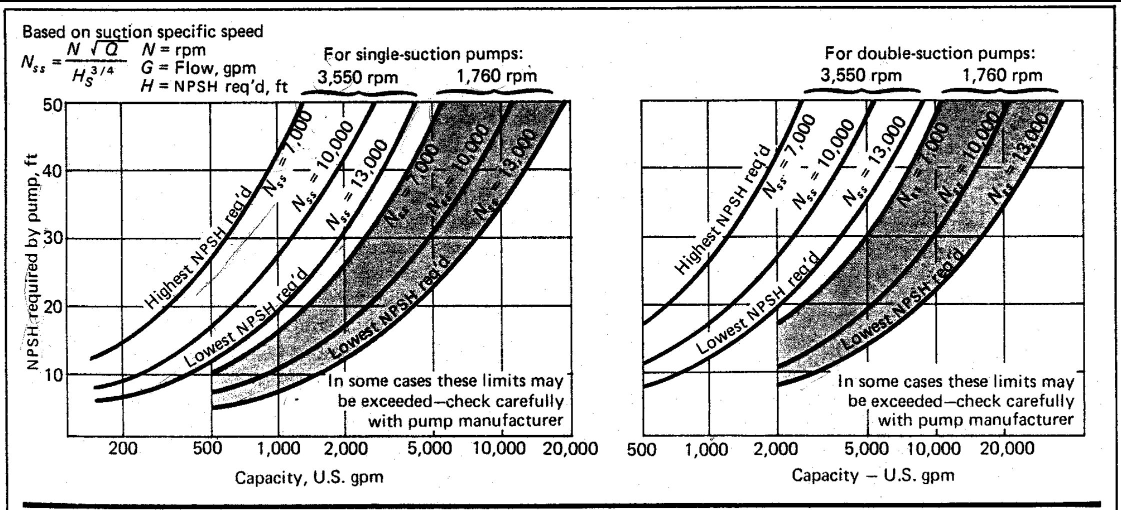
Pump selection for problem shown in Fig. 1	Table I		
Capacity, gpm 500	Sp. gr. @ temp. 0.88		
Total head, ft 550	Viscosity @ temp. 0.8 cP		
Temperature, °F 110	NPSH available, ft 20		
Manufacturer	A	B	C
Pump model or size	3×4×10½	4×6×10½	3×4×11
No. of stages	1	1	1
Speed, rpm	3570	3570	3550
Efficiency, %	71	61	69
Brake horsepower @ rated point	54.8	72.5	56.4
@ end of curve	63	95	70
NPSH required, ft.	18	9	13
Impeller dia. rated/max., in	9⅝/10½	9¾/10½	9½/11
Cost – pump with motor driver, $	6,000	6500	5,500
Power evaluation	0	+ 6,338	+ 573
Power cost basis 3 ¢ per kWh 8,000 h/yr 2 years, $	19,623	25,961	20,196
Recommendation	Based on highest efficiency ↑		

Pump selection for higher NPSH problem described in text	Table II		
Capacity, gpm 500	Sp. gr. @ temp. 0.88		
Total head, ft. 350	Viscosity @ temp. 0.6 cP		
Temperature, °F 250	NPSH available, ft Various		
Manufacturer	X	Y	Z
Pump model or size	3×4×10½	3×4×11	4×6×10½
No. of stages	1	1	1
Speed, rpm	3,570	3,570	3,570
Efficiency, %	71	69	61
Brake horsepower @ rated point	54.8	56.4	72.5
@ end of curve	63	70	95
NPSH required, ft.	18	13	9
Impeller dia. rated/max., in	9⅝/10½	9½/11	9¾/10½
Cost – pump with motor driver, $	6,000	5,500	6,500
Power evaluation	0	+ 573	+ 6338
Power cost basis 3 ¢ per kWh 8,000 h/yr 2 years, $	19,623	20,196	25,961
Recommendation	Cost of raising suction drum by 5 ft. exceeds power saving; will not pay out.	Based on adequate NPSH & near to best efficiency. ↑	Lower NPSH results in too-low efficiency — will not pay out.

♤PUMP SELECTION FOR <u>VOLATILE LIQUIDS</u>

→FIG2와 같은 EXAMPLE이나 <u>LIQUID가 VAPOR PRESSURE 근처에</u> 있고 STORED IN A SPHERE OR DRUM RATHER THAN AN ATMOSPHERIC TANKS

→TABLE2를 보면 THE HIGHER VALUE OF NPSHA MAKES POSSIBLE A MORE EFFICIENT PUMP SELECTION.



Guide to selecting NPSH required for single-and double-suction centrifugal pumps Fig. 3

→상기표는 GOOD PUMP SELECTION을 하기위해 얼만큼의 NPSH가 AVAILABE해야 하는 지의 GUIDELINE이 된다

→상기표는 Nss = N√Q/H_S $^{3/4}$를 H_S = [(N√Q)/ Nss]$^{4/3}$로 바꾸어서 일정한 Nss값, RPM에 대한 Q의 변화에 따른 Hs값을 PLOTTING한것이다

→CENTRIFUGAL PUMP는 Nss가 7000 TO 13000 OR HIGHER에서 AVAILABLE하다. 15000 이상은 INDUCER-TYPE IMPELLER(더낮은 NPSHR을 가짐)가 필요하다

→DOUBLE SUCTION IMPELLERS WILL GIVE LOWER NPSHA FOR THE SAME FLOW AND SPEED THAN SINGLE SUCTION TYPES

→WHEN THE CURVES IN FIG 3 ARE USED FOR DOUBLE SUCTION IMPELLERS, THE VALUE FOR Q MUST BE DIVIDED IN HALF

♤SELECTION OF PUMPS FOR LARGE CAPACITIES

→SYSTEM 의 PIPING 과 APPARATUS 의 SIZE 를 크게하여 HEAD 는 그대로 유지하고 FLOW 는 10 배로 한다. VOLATILE LIQUID 를 HANDLING 한다

FIG3 에서 5000 GPM 에서 SINGLE-SUCTION PUMP AT 3550RPM IS NOT REALISTIC

50FT 의 NPSHR 는 UNREASONABLE AND UNACCEPTABLE

↓

SINGLE SUCTION AT 1760RPM 은 가능

↓

최선은 DOUBLE SUCTION TYPE 으로 Nss 11000 RPM 1760 NPSHR 16FT(?)

→NPSHA > NPSHR + TWO OR THREE FT

→더더욱 큰 FLOW 에서는 1760RPM 도 부적절하고 LOWER SPEED 가 필요하다

그러나 SINGLE STAGE 의 1180RPM 의 PUMP 로는 TOTAL HEAD REQUIREMENT를 충족시키지 못하므로 MULTI STAGE PUMP 가 사용되며 TOTAL FLOW 도 TWO OR MORE UNIT 로 나눠서 문제를 해결해야 한다

HIGHER CAPACITY 는 SINGLE SUCTION 을 하든 DOUBLE SUCTION 을 하든 REALISTIC 한 NPSHR 을 위해 LOWER SPEED 로 가야하나 그렇게 되면 TOTAL HEAD REQUIREMENT 를 충족 못시키므로 MUTIL STAGE 쪽으로 가야 하며 TOTAL FLOW 를 두개내지 여러 개로 나누어야 한다(FIG3 참조할것)

DOUBLE SUCTION 은 SINGLE SUCTION 과 비교해서 동일 FLOW 에서 NPSHR 값이 작다

♤PUMPS FOR HIGHER PRESSURES

<table>
<tr>
<td>250GPM
2625FT</td>
<td>MULTI STAGE HORIZONTAL CENTRIFUGAL PUMP 를 먼저 고려
FIG1 에서 10STAGES 3550RPM 으로 가정하면
Ns 860 EFF 70% D 7.07IN
↓
SHAFT DESIGN,SHAFT DEFLECTION,INTERSTAGE CLEARANCES
CRITICAL SPEEDS: 10STAGES 이상의 HORIZONTAL PUMP 의 문제점
↓
VERTICAL SHAFT PUMP 는 SHAFT DEFLECTION AND CRITICAL SPEED 의 문제가 없다
↓
12 STAGES VERTICAL TYPE
Ns 987 D 6.78IN EFF 71%
↓
더 POPULAR한 것은 VERTICAL- OR HORIZONTAL- SHAFT PUMP AT HIGHER SPEED
ONE STAGE PUMP 이고 SPEED 의 RESTRICTION 을 없애고 INDUCE TYPE INPELLER를 사용해 NPSHR 을 LOWER 하여 유지
↓
물론 RECIPROCATING PUMP 가 MOST EFFICIENT
하지만 MAINTENANCE 비용이 많이 들고 FLOW PULSATION 때문에 ACCUMULATOR OR DAMPNER를 설치가 필요

Pump selection for high-pressure problem   Table III
Capacity, gpm 250   Sp. gr. @ temp. 0.88
Total head, ft. 2,625   Viscosity @ temp. 0.8 cP
Temperature, °F 110   NPSH available, ft 20
<table>
<tr><th>Manufacturer</th><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>Pump model or size</td><td>Horizontal 10-stage</td><td>Vertical multistage</td><td>Vertical high speed</td><td>Reciprocating plunger type</td></tr>
<tr><td>No. of stages</td><td>10</td><td>12</td><td>1</td><td>5 cylinders</td></tr>
<tr><td>Speed, rpm</td><td>3,550</td><td>3,550</td><td>16,200</td><td>320</td></tr>
<tr><td>Efficiency, %</td><td>67.5</td><td>68</td><td>62</td><td>90</td></tr>
<tr><td>Brake horsepower @ rated point</td><td>216</td><td>215</td><td>235</td><td>162</td></tr>
<tr><td>@ end of curve</td><td>238</td><td>254</td><td>250</td><td>Max. 200</td></tr>
<tr><td>NPSH required, ft.</td><td>10</td><td>8</td><td>10</td><td>29*</td></tr>
<tr><td>Impeller dia. rated/max., in</td><td>8 1/4 / 8 3/8</td><td>7 11/16 / 7 13/16</td><td>5</td><td>—</td></tr>
<tr><td>Cost —pump with motor driver, $</td><td>50,000</td><td>70,000</td><td>35,000</td><td>65,000</td></tr>
<tr><td>Power evaluation</td><td>+25,920</td><td>+25,440</td><td>+35,040</td><td>0</td></tr>
<tr><td>Power cost basis 3 ¢ per kWh 8,000 h/yr 2 years, $</td><td>103,680</td><td>103,200</td><td>112,800</td><td>77,760</td></tr>
<tr><td>Recommendation</td><td>Most likely choice of convent-ional style pump. ↑</td><td>Very small power saving does not warrant added cost.</td><td>Lowest first cost. Might be seriously considered. ↑ ?</td><td>Although highest in efficiency this would probably not be chosen for a modern plant
*Too high.</td></tr>
</table>
</td>
</tr>
<tr>
<td>50GPM
2625FT</td>
<td>RECIPROCATING PUMP 나 HIGH SPEED PARTIAL EMISSION TYPE CENTRIFUGAL 이 ONLY SOLUTION
3550RPM 의 REASONABLE MULTI STAGE CENTRIFUGAL PUMP 는 DESIGN 될수 없다</td>
</tr>
<tr>
<td>5000GPM
2652FT</td>
<td>HORIZONTAL MULTISTAGE CENTRIFUGAL PUMP 가 VIABLE ALTERNATIVE</td>
</tr>
</table>

♤PUMPS FOR VISCOUS LIQUIDS

→KINEMATIC VISCOSITY(CST)=ABSOLUTE VISCOSITY(CP)/SP GR OF LIQUID

→SSU = 4.62 X CST (ABOVE 250 SSU)

→어떤 유체의 VISCOSITY 는 온도에 따라 변한다(온도가 높을수록 낮아진다)

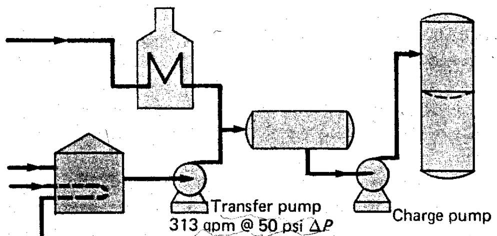
→VISCOUS 한 LIQUID 를 PUMPING 하기 위한 BEST CHOICE 는 POSITIVE DISPLACEMENT PUMP 즉 ROTARY PUMP 나 RECIPROCATING PUMP 이다

→ROTARY PUMP-GEAR,SCREW OR LOBE TYPES 는 VISCOUS LIQUID 에서 BEST PERFORMANCE 를 나타내며 THE HIGHEST VISCOSITIES 에서는 유일하게 사용할수 있는 TYPE 이다

→LOW VISCOSITY 에서 SLIP 이 ROTARY PUMP 에서 상당히 크고 이것은 HIGHER VISCOSITY 에서 RATED CAPA 보다 PUMP CAPA 를 줄인다

→RECIPROCATING PUMP 도 REDUCED SPEED 를 가지고 VISCOUS 한 LIQUID 에서 BEST PERFORMANCE 를 나타내는데 요구되는 DISCHARGE PRESSURE 가 500PSI 나 그 이상일 때 RECIPROCATING PUMP 가 BEST CHOICE 이다

→CENTRIFUGAL PUMP 는 1000SSU 까지 그리고 때때로 그 이상의 VISCOSITY 에서 사용된다



Fluid	Transfer pump Heavy oil	
Pumping temp. °F.	600°	400°
Sp. gr. @ pumping temp.	0.88	0.96
Viscosity at pumping temp.	8 cP	150 cP
Normal gpm at pumping temp.	285	285
Overcapacity, %	10%	10%
Rated gpm at pumping temp.	313	313

Flow-sketch for heavy oil example Fig. 5

Viscous performance of rotary pumps Table IV

IV-1 A	IV-1 B	Operating case	IV-2 A	IV-2 B
313	313	Required capacity, gpm	313	313
50	50	Differential pressure, psi	50	50
8	150	Viscosity, cP	8	150
600	400	Temperature, °F	600	400
Screw-type rotary (external bearing) 6 X 4 in.		Type and size of pump	1-stage centrifugal 3 X 4 X 8 1/2 in.	
1,760 rpm		Operating speed	3,550 rpm	
313	334	Delivered capacity, gpm	325	313
61%	38%	Approx. efficiency	66%	44%
15	26	Approx. horsepower required	15	21

SCREW TYPE ROTARY	CENTRIFUGAL
→높은 PT 때문에 ROTARY PUMP 는 부적합 →400°F가 대부분의 ROTARY PUMP 의 UPPER OPERATING LIMITS 이다 →이같이 높은 온도에는 EXTERNAL TIMING GEAR 을 가진 SCREW PUMP 가 적절 →PUMP 는 낮은 VISCOSITY 에서 충분한 CAPA 를 제공하기위해 VISCOUS CONDITION 에 대해 OVERSIZE 되어야하며 이것은 낮은 VISCOSITY 에서 증가되는 SLIP 때문이다 →반대:FOUR STUFFING BOXES 를 가지고 있고 POSITIVE DISPLACEMENT PUMP 의 OUTPUT 은 THROTTLE 될수없다(원심펌프는 가능)	→VISCOSITY 가 증가함에 따라 EFFICIENCY 가 상당히 감소 →낮은 펌프 효율을 감안하여 DIRVER가 충분히 커야한다

♤PUMPS FOR SLURRY SERVICE

→EITHER CENTRIFUGAL OR POSITIVE-DISPLACEMENT PUMPS CAN HANDLE A MIXTURE OF SOLIDS AND LIQUIDS, SOMETIMES CALLED TWO-PHASE FLOW, OR SLURRY PUMPING.

→SLURRY SERVICE 에 있는 CENTRIFUGAL PUMP 도 CLEAN LIQUID 를 PUMPING 할때의 LAW 와 PRINCIPLE 을 따르지만 적절한 PUMP 선택을 위해 MIXTURE 속에 있는 SOLID 의 영향을 고려해야한다

→고려사항

;SP GR OF THE SOLIDS, THE FLUID, THE MIXTURE, CONCENTRATION BY VOLUME(Cv), CONCENTRATION BY WEIGHT(Cw)

;SOLID 의 NATURE 를 고려하여 ABRASION 과 WEAR 에 강한 MATERIAL 선택

;CLEAN WATER를 근간으로한 PUMP 의 PERFORMANCE 는 SP GR, CONCENTRATION OF SOLIDS, VISCOSITY OF MIXTURE, SLIP 등으로 인해 DERATED 한다

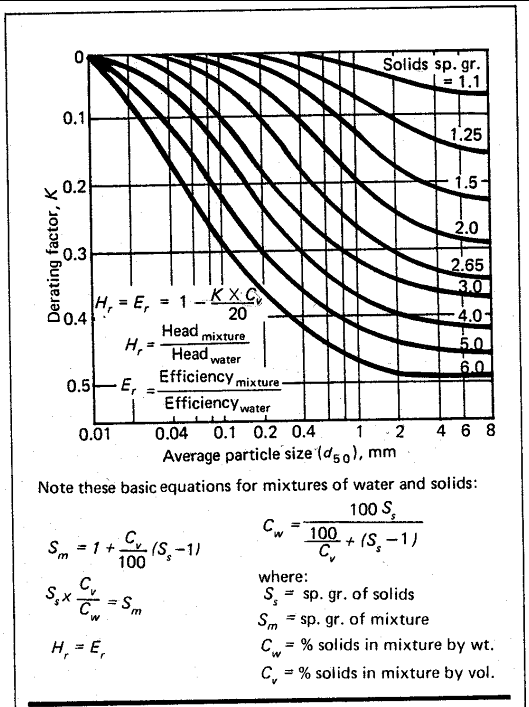
;PUMP 는 CLEAR LIQUID 를 PUMPING 할때보다 SLOW 하게 운전되어야 WEAR 과 ABRASION 을 막고 LONGER LIFE 를 가질수 있다

→SLURRY PUMP 도 " AFFINITY LAWS" 를 따른다

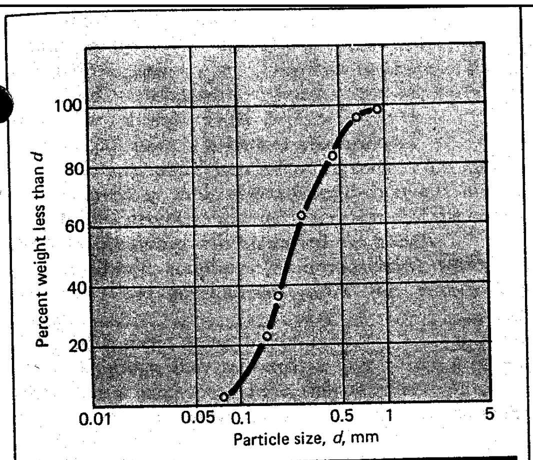
RPM1/RPM2 = Q1/Q2 = 3 √ (H1/H2)= 3 √ (HP1/HP2)

→VARIABLE SPEED, AND PROVISION FOR SELECTING ANY EXACT SPEED, ARE EXTREMELY IMPORTANT FOR SLURRY PUMPS

♤SLURRY-PUMP SELECTION : EXAMPLE



Slurry factor chart for head and efficiency Fig. 7



Particle-size curve Fig. 8

Problem: to pump 1,000 gpm of sodium carbonate crystalline slurry in water.

Specific gravity of solids (S_s) = 2.46 and concentration by weight (C_w) = 25%. The total head required is 47 feet. Particle sieve analysis and average particle size determinations are as follows:

U.S. mesh	% by weight solid	Particle size	Accumulated % passing
+200	3	0.074 mm	3
+140	9	0.105 mm	12
+100	10	0.149 mm	22
+ 80	15	0.177 mm	37
+ 60	27	0.250 mm	64
+ 40	20	0.42 mm	84
+ 30	13	0.59 mm	97
+ 20	3	0.84 mm	100

(1) Plot on semi-logarithmic paper and read $d_{50} = 0.2$ mm (Fig. 8)

(2) Determine concentration of solids by volume (C_v) (Fig. 7)

$$C_w = 25\% = \frac{(100)(2.46)}{\frac{100}{C_v} + (2.46 - 1)} ; C_v = 11.9\%$$

(3) Determine specific gravity of mixture by reference to Fig. 7

$$S_m = 1 + \frac{11.9}{100}(2.46 - 1) = 1.173$$

(4) Determine head and efficiency reduction, H_r and E_r (Fig. 7)

For $d_{50} = 0.2$ and $S_s = 2.46$, read $K = 0.08$ calculate $H_r = 0.952 = E_r$

(5) Determine head required on clear water

$$H_w = \frac{H_{mix}}{H_r} \text{ or } \frac{47}{0.952} = 49 \text{ ft.}$$

(6) Select a suitable slurry pump from manufacturer's printed curves, running at slowest speed with maximum-diameter impeller (6- × 8-in. pump, 880 rpm, 14.75-in. impeller, 78% efficiency, per Fig. 9)

♤SPEED VARIATION FOR SLURRY-PUMPS

→VARIABLE-SPEED DRIVES 의 종류와 잇점

종류	잇점
→VARIABLE-PITCH V BELT OR CHAIN DRIVES →VARIABLE-SPEED ELECTRIC MOTORS, SUCH AS D C MOTORS, OR TWO-SPEED OR MULTI SPEED WOUND ROTOR A C MOTOR →EDDY-CURRENT COUPLINGS,WHERE SPEED OF THE OUTPUT SHAFT TO THE PUMP WILL BE VARIED ELECTRICALLY →HYDRAULIC COUPLING (FLUID COUPLING),WHERE THE HYDRAULIC-FLUID MECHANISM VARIES THE OUTPUT-SHAFT SPEED	→INITIAL INVESTMENT 는 높다 →VARIATIONS IN FLOW RATE, HEAD →WEAR 로 인한 PUMP PERFORMANCE 의 감소가 있어도 당분간 REQUIED RATE OF FLOW AND HEAD 를 PUMP 할수있다 →초창기 SYS CALCULATION 에서 있을수있는 ERROR 를 CORRECTION

♤LIMITATIONS ON SLURRY PUMPS

→SPECIAL DESIGN 이지 않는한 HEAD DEVELOPED PER IMPELLER 는 180 TO 220FEET

→IMPELLER-TIP SPEED 는 SEVERE-ABRASIVE SERVICE 에서 3500 TO 4500 FT/MIN (CLEAR LIQUID 를 다루는 CENTRIFUGAL PUMP 는 이 속도의 2~3 배이다)

→HIGHEST HEAD OR PRESSURE, REQUIREMENTS WILL PROBABLY REQUIRE RECIPROCATING TYPE PUMPS

→THICKEST UNPREDICTABLE MIXTURES THAT CANNOT BE PUMPED BY CENTRIFUGAL PUMPS MAY REQUIRE AIR-OPERATED OR MOTOR-OPERATED DIAPHRAGM PUMPS

→CENTRIFUGAL PUMP 가 적절히 선정되었다 할지라도 많은 RUBBER-LINED OR HARD-METAL PUMP 는 지속적인 SERVICE 하에서 몇 주 못간다

<첨부 1>

SHEET 2 OF 3

SK Corp. **PUMP & LINE CALCULATION SHEET**

1	Client			SK Corp.			
2	Project and Location			SMB(n-Paraffin)	NAC #1 PX	Item No.	AD-P2002A/B
3	Service Conditions	Fluid Material		C10 + ARO			
4		Flow Rate, Normal/Rated	(kg/hr)	3776 / 4153			
5		MW		114.5			
6		Temperature	(℃)	144			
7		Flowing sp.gr.		0.651			
8		Flow Rate, Volume, Normal/Rated	(m3/hr)	5.8 / 6.38			
9		Viscosity	(cP)	0.202			
10		Vapor Press. at PT, Pv	(kg/cm2A)	1.633			
11		Excess Capacity	(%)	10			
12				Suction	Discharge		
13	Line Friction	Segment		ⓐ	ⓑ	ⓒ	
14		Design Flow	(m3/hr)	6.38	6.38	4.91	
15		Line Size, nominal & Sch. No.		2" SCH 40	.1/2" SCH 4	.1/2" SCH 4	
16		Pipe I.D.	(mm)	52.5	40.89	40.89	
17		Equivalent Length	(m)	6.796	8.858	511.3	
18		Velocity	(m/s)	0.8182	1.349	1.038	
19		Press. Drop	(kg/cm2/100m)	0.0893	0.3195	0.1925	
20		Reducer and Expander	(kg/cm2)	0	0	0	
21		Segment Press. Drop	(kg/cm2)	0.009	0.042	1.476	

					Rated	Maximum
22					Rated	Maximum
23	Suction	Press. at Equipment	(kg/cm2g)	+	0.60	+
24		Liquid Static Head	(kg/cm2)	+	0.20	+
25		Line Press. Drop	(kg/cm2)	-	0.009	
26		Other (valve, strainer, etc.) △P	(kg/cm2)	-	0.03	
27		Pump Suction Press. Net. Ps	(kg/cm2g)		0.756	
28						
29	Discharge	Destination	(kg/cm2g)	+	10	
30		Static Head	(kg/cm2)	+	0.39	
31		Line Press. Drop	(kg/cm2)	+	1.52	
32		Exchangers Press. Drop	(kg/cm2)	+	0.7	
33		Control Valve Press. Drop	(kg/cm2)	+	1.21	
34		Other (furnace etc.) △P	(kg/cm2)	+	0.2	
35		Pump Discharge Press.	(kg/cm2g)		14.02	
36						
37	NPSH	Pump Suction Press. net. Ps	(kg/cm2a)	+	1.79	
38		Vapor Press. at PT, Pv	(kg/cm2a)	-	1.633	
39		Avaliable NPSH	(m)		2.4	

40			
41	Design Disch. Press.	(kg/cm2g)	14.02
42	Design Suction Press.	(kg/cm2g)	0.76
43	Design Diff. Press.	(kg/cm2)	13.26
44	Disign Diff. Head	(m)	204
45			
46	Hydraulic HP	(HP)	3.08
47		(kw)	2.30
48	Estimated Pump Efficiency	(%)	
49	Estimated BHP	(kw)	
50	Driver HP	(kw)	
51	Type of Pump		CENTRIFUGAL
52	Type of Driver		MOTOR
53			
54	Not REPORT		
55			
56			
57			
58			

< See Attached >

UNIT SK CORPERATION

SERVICE

(ITEM NO.)

JOB CODE

DATE : ######## REV. A

PREP'D KMS CHK'D KSP APP'D SHK

CALCULATION SHEET NO. /

FORM ENG-M1-2-01

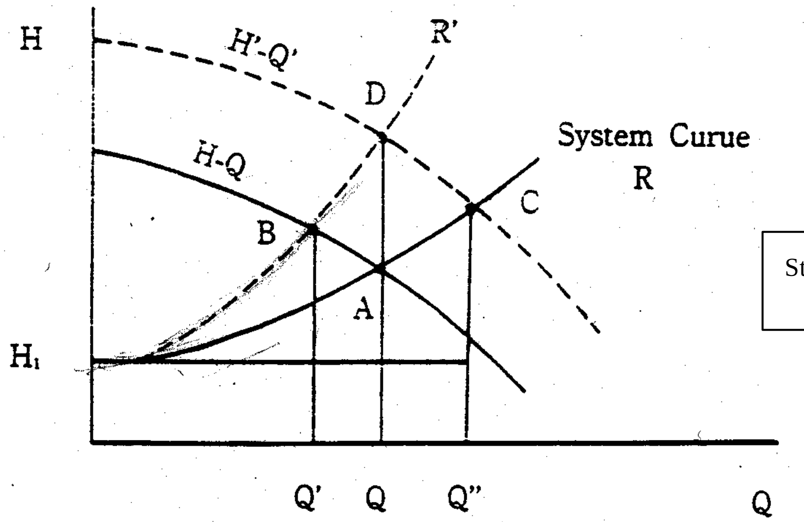
<첨부 2>

Capacity (gpm)	Static Suction Head h_{ss} (feet)	Suction Surface Pressure h_{ps} (feet, gauge)	Suction Friction Loss h_{fs} (feet)	Total Suction Head h_s (feet, gauge)
40	−5	0	0.2	−5.2
80	−5	0	0.8	−5.8
120	−5	0	1.8	−6.8
160	−5	0	3.1	−8.1
200	−5	0	4.8	−9.8

Capacity (gpm)	Static Discharge Head h_{sd} (feet, gauge)	Suction Surface Pressure h_{pd} (feet, gauge)	Discharge Friction Loss h_{fd} (feet)	Total Discharge Head h_d (feet, gauge)
40	10	19.3	2.8	32.1
80	10	19.3	10.3	39.6
120	10	19.3	22.4	51.7
160	10	19.3	39.1	68.4
200	10	19.3	60.4	89.7

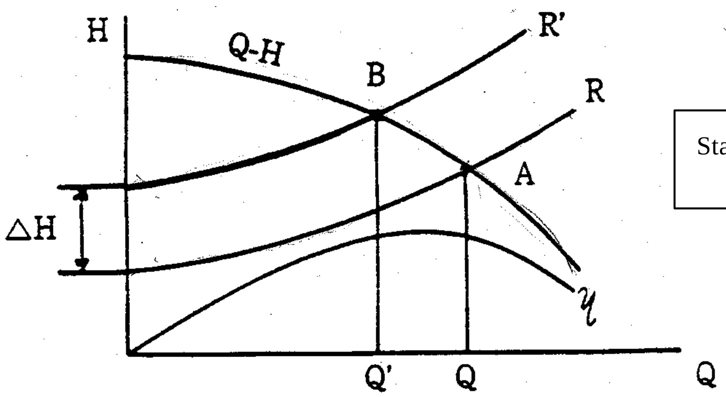
Capacity (gpm)	Total Discharge Head h_d (feet, gauge)	Total Suction Head h_s (feet, gauge)	Total System Head H (feet)
40	32.1	−5.2	37.3
80	39.6	−5.8	45.4
120	51.7	−6.8	58.5
160	68.4	−8.1	76.5
200	89.7	−9.8	99.5

<첨부 3>

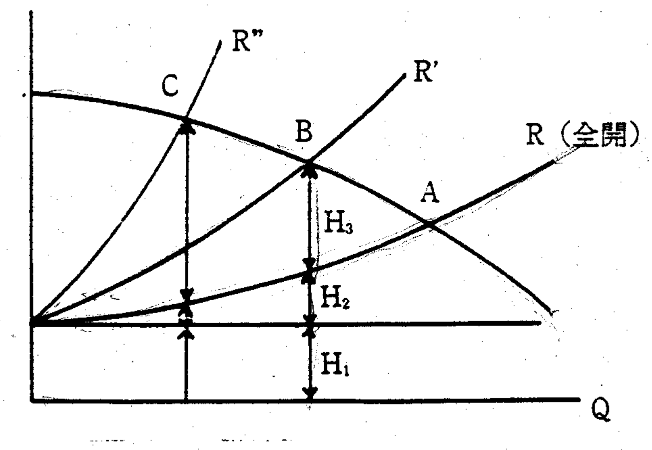


H₁ : Static Head

Static head 가 일정



Static head 가 변함

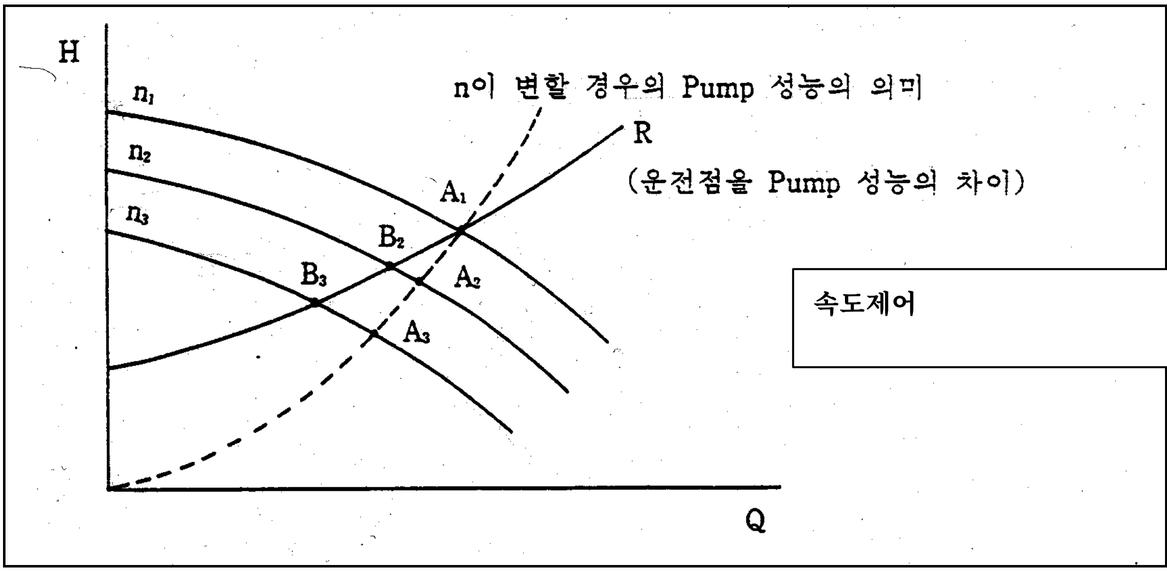


Valve 제어

H₁ : Static Head

H₂ : Friction Loss

H₃ : Valve Throttling Loss



속도제어