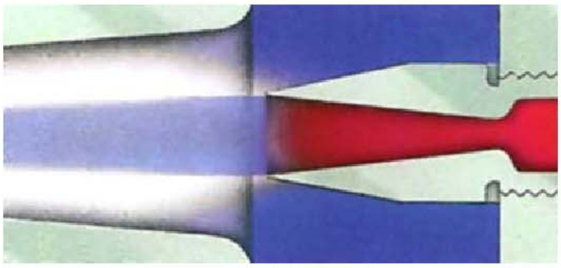
EJECTORS

- PRINCIPLES
- APPLICATION
- DESIGN FOR STEAM JET AIR EJECTOR (SJAE)
- PHOTOS
- ATTACHMENT - VACUUM FOR POWER PLANT

SamWon Engineering Co.,Ltd.

PRINCIPLES



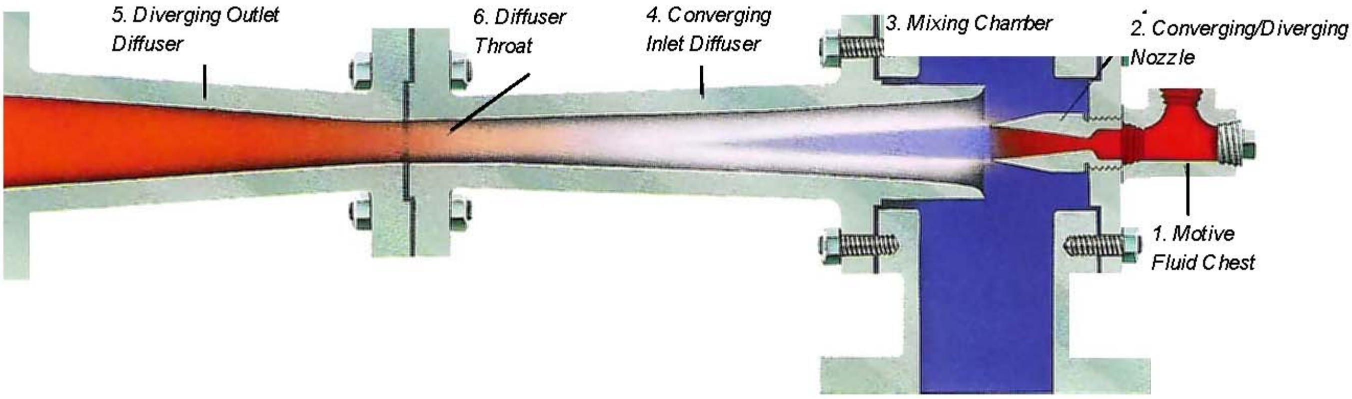
Ejectors consist of six basic parts:

1. Motive Fluid Chest
2. Converging/Diverging Nozzle
3. Mixing Chamber
4. Converging Inlet Diffuser
5. Diverging Outlet Diffuser
6. Diffuser Throat

The operating principle of the ejector is that the pressure energy in the motive fluid (1) is converted to velocity energy by an adiabatic expansion in the Converging/Diverging Nozzle (2). The Nozzle exit velocity is normally in the supersonic range of 3000 to 4000 feet/second when using steam as the motive fluid. (Velocities may vary depending on molecular weight, temperature, and pressure of the motive fluid.)

This high-velocity (cone shaped) jet enters the Mixing Chamber (3) and entrains the suction fluid being pumped. The mixture attains a velocity of approximately 2000 to 3000 feet per second.

The mixed motive fluid and suction fluid then enter the Converging Inlet Diffuser (4) where a portion of the velocity energy is converted to pressure energy. The mixture is then compressed in the Diverging Outlet (5) section of the Diffuser to attain the final discharge pressure, normally 5 to 15 times the suction pressure. There is a corresponding rise in mixture temperature as this compression occurs.



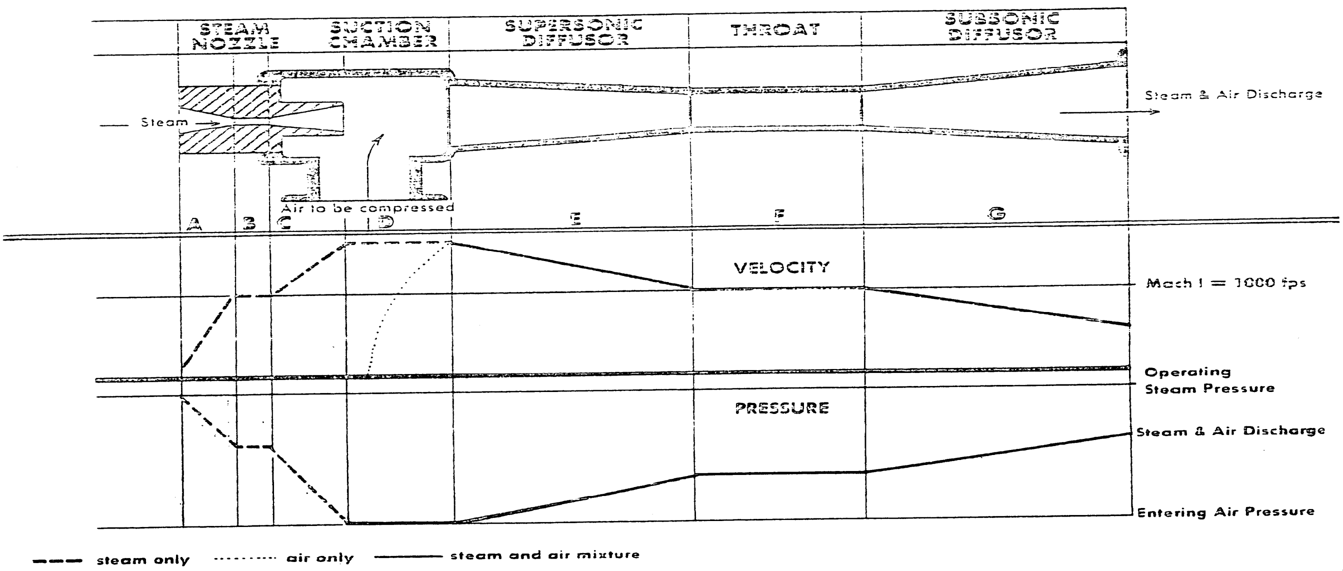


Figure 6-1. Basic ejector components and diagram of energy conversion in nozzle and diffuser. By permission, Ingersoll-Rand Co.

Steam Jets Serve the Entire Pressure Range

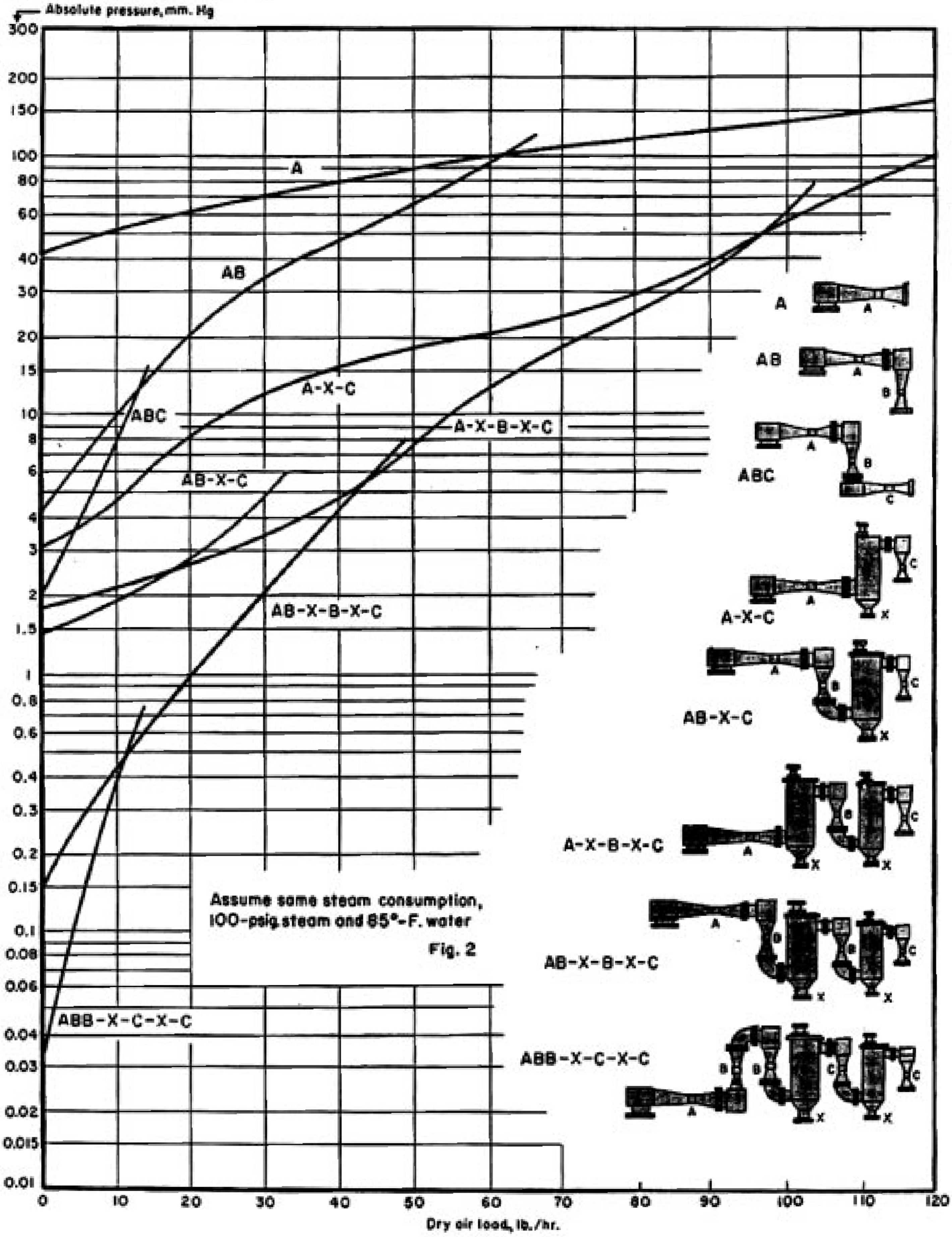


Fig. 2

APPLICATION

REFINING

***Crude oil vacuum distillation*:**

Three-stage Ejectors

Precondenser with two-stage Ejectors

Precondenser with Liquid Ring Vacuum Pump

Lube oil dryers:

Single-stage Ejectors

Two-stage Ejectors

Liquid Ring Vacuum Pumps

PROCESS

units used for urea, synthetic fibers, pharmaceuticals, tobacco drying, crystallizers, evaporators, and desalinization.

POWER

Steam surface condensers:

Twin-element two-stage Ejectors

Liquid Ring Vacuum Pumps

Combination Steam Ejector/ Liquid Ring Vacuum Pump

Three-stage Ejector system in refinery service.

Ejectors in vacuum distillation service.

Triple element booster Ejectors in refinery service.

Combination system for polyester plant.

Ejector and Condensers in a urea plant.

Combination system with graphite intercondenser for a pharmaceutical plant.

Large Condenser exhauster system.

Booster Ejectors and Condensers for enhanced venting of surface condenser.

A 166,000 sq.ft. steam surface Condenser.

APPLICATION

GEOTHERMAL STEAM CONDENSERS AND GAS REMOVAL SYSTEMS

Graham has many years of experience designing systems with high non-condensible gas loadings. Since geothermal steam is highly corrosive and contains large amounts of noncondensible gases (1-10%), the design and fabrication of Geothermal Steam Condensers is radically different than conventional power plant condensers. Special consideration must be given to:

- Reduced overall heat transfer rates (U value) and weighted LMTD due to noncondensible gases.
- Flow path for venting large volumes of noncondensible gases.
- Pressure drop of noncondensible gases.
- Subcooling of noncondensible gases.
- Preventing subcooling of the condensate.
- Special materials to prevent corrosion.

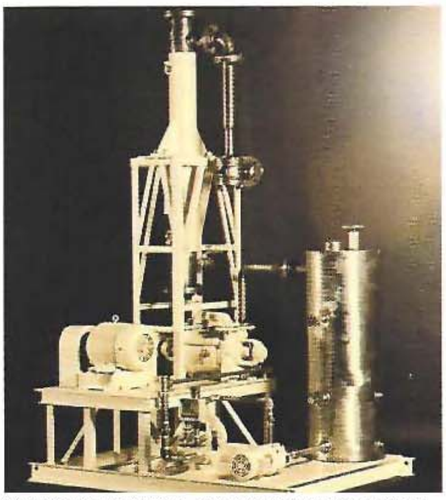
The associated vacuum system can be multi-stage Steam Ejectors or a combination of a Steam Ejector and Liquid Ring Vacuum Pump. Since these systems are very large, Graham engineers will carefully evaluate the design and selection of components for each application, to provide the most efficient system.

A 54,000 sq. ft. steam surface condenser for 32 MW geothermal power plant in California.

Direct contact geothermal condenser for 9 MW plant.

FOOD

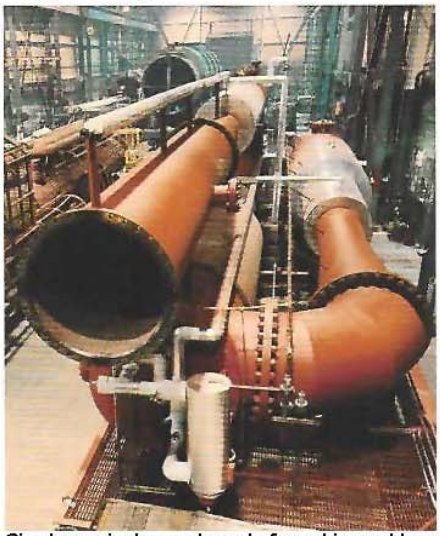
For flash cooling, evaporators, degassing, and deodorizing.



Combination ejector and liquid ring pump for a juice evaporator.

METAL REFINING

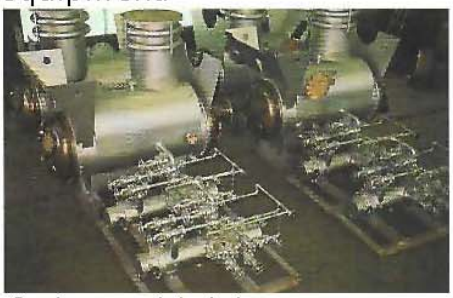
For vacuum melting and vacuum degassing.



Six stage ejector package before shipment to a steel company.

MARINE

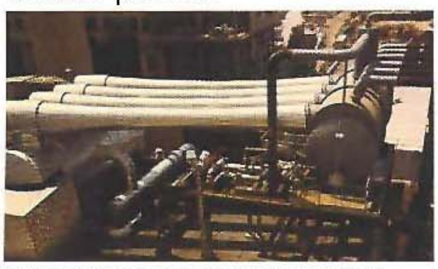
Ejectors for main and auxiliary Condensers and distilling equipment.



Condensers and air ejectors.

PULP AND PAPER

Liquid Ring Vacuum Pumps:
Steam Vacuum Refrigeration
to chill water for chlorine dioxide bleach plants.



3,400 ton steam vacuum refrigeration unit.

DESIGN

* MPS FOR NUEVA PROJECT

CAPACITY SUMMARY SHHET for Steam Jet Air Ejector

Design Conditions :

Total No of system	1	set	
Steam jet air ejector	2	sets	1st 100% x 1, 2nd 100% x 1
Ejector condenser	1	sets	Integral 1st 100% x 1 plus 2nd 100% x 1
Hogging ejector	1	set	1 x 100%
Silencer for Hogging Ejector	1	set	1 x 100%
All required valves, piping, instruments,	1	lot	
counter flange, bolts, nuts, washers, gaskets			
Skid (all equipments mounted)	1	set	

Design Capacity :

Holding	Capacity, total	99	kg/h	@ 25.4 mmHgA Design
	Dry air	31	kg/h	@ 25.4 mmHgA Design
	Water vapor	68	kg/h	@ 25.4 mmHgA Design
	Condenser press	4	kpaA	
	Condenser temp	28.98	°C	
Hogging	Capacity, total	10,000	m^3	@ 254 mmHgA Design
	Air	10,000	m^3	@ 254 mmHgA Design
	Time	Bellow 30	min.	

Motive Steam for Ejector Condition

Flow		kg/h	To be specified by Supplier
Inlet press	15	barA	
Inlet temp	Sat. Temp.+50	°C	

Cooling Water for Ejector Condenser

Flow	152,940	kg/h
Inlet press	15	barA
Inlet temp	29.09	°C

DESIGN

* CALCULATION FOR HOGGING

– Volume of load

Steam from turbine exhasut		508,500	kg/hr
		1,121,243	lbs/hr
According to HEI code		700	CFM
Standards for Steam Surface condensers	Dry Air :	315	lbs/hr
para 6.0 Venin Equipment capacities	Water Vapor :	693	lbs/hr
Table 8 (1,000,000 ~ 2,000,000 lbs/hr)	Total Mixture :	1,008	lbs/hr

– Weight of load

W : Weight of Gas (Air) **1.429** kg/hr

– Suction Condition

Ls : Load (kg/hr)	=	1429	Weight of Load
Ps : Pressure (mmHg A)	=	***254***	

– Motive Condition

Lm : Load (kg/hr)	=	3040	Motive Suction Consumption
Pm : Pressure (kg/㎠ A)	=	15	

– Discharge Condition

Ld : Load (kg/hr)	=	4469	=Ls + Lm
Pd : Pressure (mmHg A)	=	800	*

*** The discharge pressure has to design more than atomospheric pressure (760mmHg A), or less than the suction pressure for next stage.**

DESIGN

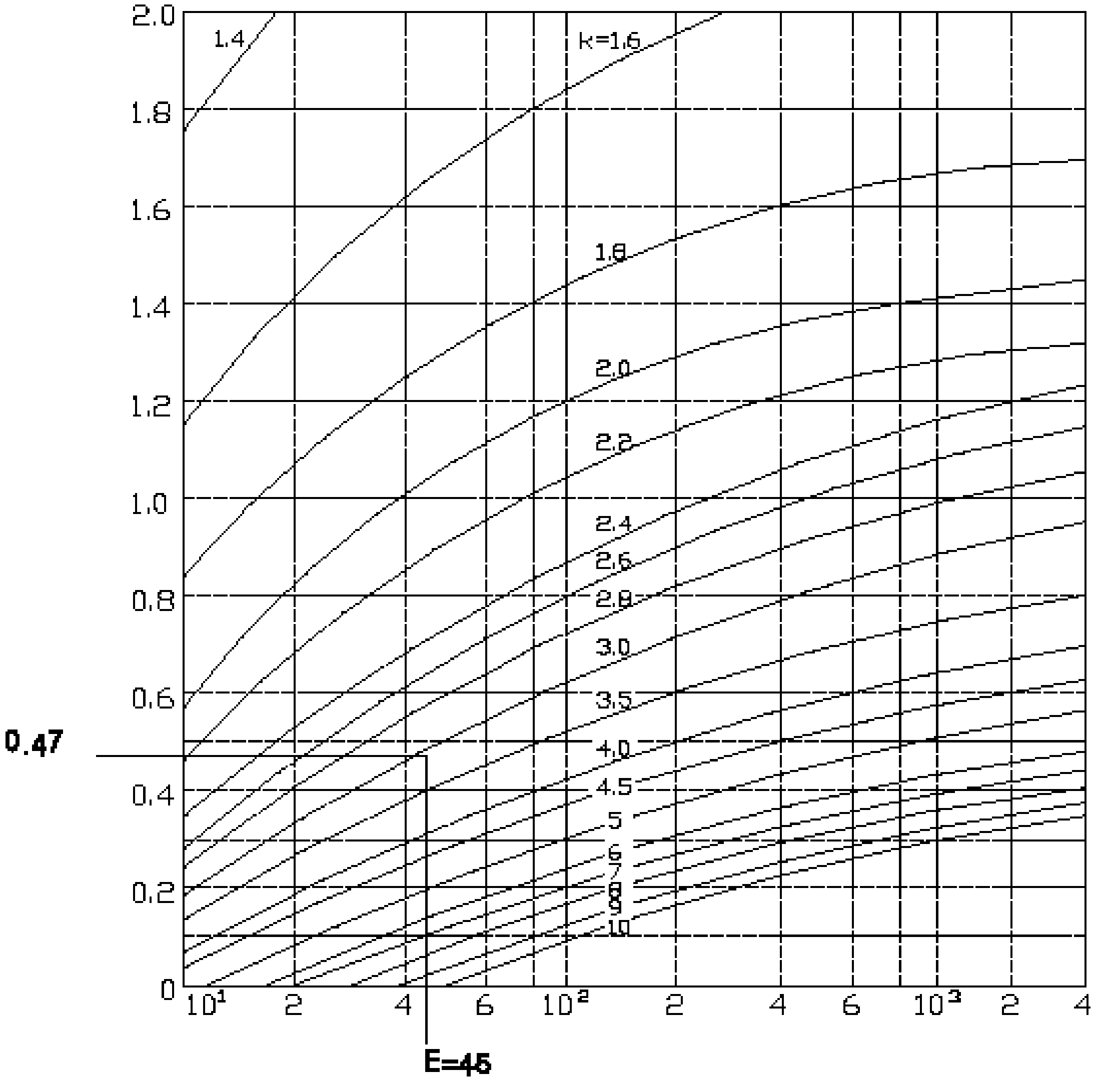
* CALCULATION FOR HOGGING

- Expansion Ratio (E)

$$E = \frac{\text{Motive Pressure (mmHg A)}}{\text{Suction Pressure (mmHg A)}} = \frac{11,400}{254} = 45$$

- Consumption Ratio (K)

$$K = \frac{\text{Discharge Pressure (mmHg A)}}{\text{Suction Pressure (mmHg A)}} = \frac{800}{254} = 3.15$$



- Suction Ratio Graph : α = 0.47

- Motive Suction Consumption

$$= \frac{\text{Suction Condition Load (kg/hr)}}{\text{Suction Ratio Graph } (\alpha)} = \frac{1,429}{0.47} = 3,040 \text{ kg/hr}$$

DESIGN

* CALCULATION FOR HOGGING

RAPID EVACUATION EQUIPMENT CAPACITIES

Total Steam Condensed lbs/hour	*SCFM – Dry Air at 10 in HgA Design Suction Pressure
Up to 100,000	50
100,001 to 250,000	100
250,001 to 500,000	200
500,001 to 1,000,000	350
1,000,001 to 2,000,000	700
2,000,001 to 3,000,000	1050
3,000,001 to 4,000,000	1400
4,000,001 to 5,000,000	1750
5,000,001 to 6,000,000	2100
6,000,001 to 7,000,000	2450
7,000,001 to 8,000,000	2800
8,000,001 to 9,000,000	3150
9,000,001 to 10,000,000	3500

Note: In the range of 500,000 lbs/hr steam condensed and above, the above table provides evacuation of the air in the condenser and L.P. turbine from atmospheric pressure to 10 in. HgA in about 30 minutes if the volume of condenser and L.P. turbine is assumed to be 26 cu ft / 1000 lb/hr of steam condensed.
*SCFM - 14.7 psia at 70°F - to convert to lbs./hr. multiply above values by 4.5.

Table 8

VENTING EQUIPMENT CAPACITIES
A. One Condenser Shell

Effective Steam Flow *Each* Main Exhaust Opening lbs/hr		Total Number of Exhaust Openings								
		1	2	3	4	5	6	7	8	9
Up to 25,000	*SCFM	3.0	4.0	5.0	5.0	7.5	7.5	7.5	10.0	10.0
	Dry Air lbs/hr	13.5	18.0	22.5	22.5	33.8	33.8	33.8	45.0	45.0
	Water Vapor lbs/hr	29.7	39.6	49.5	49.5	74.4	74.4	74.4	99.0	99.0
	Total Mixture lbs/hr	43.2	57.6	72.0	72.0	108.2	108.2	108.2	144.0	144.0
25,001 to 50,000	*SCFM	4.0	5.0	7.5	7.5	10.0	10.0	10.0	12.5	12.5
	Dry Air lbs/hr	18.0	22.5	33.8	33.8	45.0	45.0	45.0	56.2	56.2
	Water Vapor lbs/hr	39.6	49.5	74.4	74.4	99.0	99.0	99.0	123.6	123.6
	Total Mixture lbs/hr	57.6	72.0	108.2	108.2	144.0	144.0	144.0	179.8	179.8
50,001 to 100,000	*SCFM	5.0	7.5	10.0	10.0	12.5	12.5	15.0	15.0	15.0
	Dry Air lbs/hr	22.5	33.8	45.0	45.0	56.2	56.2	67.5	67.5	67.5
	Water Vapor lbs/hr	49.5	74.4	99.0	99.0	123.6	123.6	148.5	148.5	148.5
	Total Mixture lbs/hr	72.0	108.2	144.0	144.0	179.8	179.8	216.0	216.0	216.0
100,001 to 250,000	*SCFM	7.5	12.5	12.5	15.0	17.5	20.0	20.0	25.0	25.0
	Dry Air lbs/hr	33.8	56.2	56.2	67.5	78.7	90.0	90.0	112.5	112.5
	Water Vapor lbs/hr	74.4	123.6	123.6	148.5	173.1	198.0	198.0	247.5	247.5
	Total Mixture lbs/hr	108.2	179.8	179.8	216.0	251.8	288.0	288.0	360.0	360.0
250,001 to 500,000	*SCFM	10.0	15.0	17.5	20.0	25.0	25.0	30.0	30.0	35.0
	Dry Air lbs/hr	45.0	67.5	78.7	90.0	112.5	112.5	135.0	135.0	157.5
	Water Vapor lbs/hr	99.0	148.5	173.1	198.0	247.5	247.5	297.0	297.0	346.5
	Total Mixture lbs/hr	144.0	216.0	251.8	288.0	360.0	360.0	432.0	432.0	504.0
500,001 to 1,000,000	*SCFM	12.5	20.0	20.0	25.0	30.0	30.0	35.0	40.0	40.0
	Dry Air lbs/hr	56.2	90.0	90.0	112.5	135.0	135.0	157.5	180.0	180.0
	Water Vapor lbs/hr	123.6	198.0	198.0	247.5	297.0	297.0	346.5	396.0	396.0
	Total Mixture lbs/hr	179.8	288.0	288.0	360.0	432.0	432.0	504.0	576.0	576.0
1,000,001 to 2,000,000	*SCFM	15.0	25.0	25.0	30.0	35.0	40.0	40.0	45.0	50.0
	Dry Air lbs/hr	67.5	112.5	112.5	135.0	157.5	180.0	180.0	202.5	225.0
	Water Vapor lbs/hr	148.5	247.5	247.5	297.0	346.5	396.0	396.0	445.5	495.0
	Total Mixture lbs/hr	216.0	360.0	360.0	432.0	504.0	576.0	576.0	648.0	720.0
2,000,001 to 3,000,000	*SCFM	17.5	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
	Dry Air lbs/hr	78.7	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0
	Water Vapor lbs/hr	173.1	247.5	297.0	346.5	396.0	445.5	495.0	544.5	594.0
	Total Mixture lbs/hr	251.8	360.0	432.0	504.0	576.0	648.0	720.0	792.0	864.0
3,000,001 to 4,000,000	*SCFM	20.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0
	Dry Air lbs/hr	90.0	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5
	Water Vapor lbs/hr	198.0	297.0	346.5	396.0	444.5	495.0	544.5	594.0	613.5
	Total Mixture lbs/hr	288.0	432.0	504.0	576.0	648.0	720.0	79992.0	864.0	936.0

*14.7 psia at 70°F
Note: These tables are based on air leakage only and the air vapor mixture at 1 inch HgA and 71.5°F.

Table 9A

DESIGN

* CALCULATION FOR 1ST HOLDING

– Weight of load

HEI Standard (6.0 Venting equipment capacity) it follows.

Dry Air :	67.5 lbs/hr = 31.0 kg/hr
Water Vapor :	148.5 lbs/hr = 68.0 kg/hr
Total Mixture :	216.0 lbs/hr = 99.0 kg/hr
Mole Weight :	20.31

– Suction Condition

Ls	: Load (kg/hr)	=	99.0	Weight of Load
Ps	: Pressure (mmHg A)	=	25.4	

– Motive Condition

Lm	: Load (kg/hr)	=	295	Motive Suction Consumption
Pm	: Pressure (kg/㎠ A)	=	15	

– Discharge Condition

Ld	: Load (kg/hr)	=	394.2	=Ls + Lm
Pd	: Pressure (mmHg A)	=	148	*

*** The discharge pressure has to design more than atomospheric pressure (760mmHg A), or the suction pressure for next stage.**

– Dry Air Equivalent

$$AE = \frac{Ls}{0.86} = \frac{99.0}{0.86} = \mathbf{115} \text{ kg/hr}$$

DESIGN

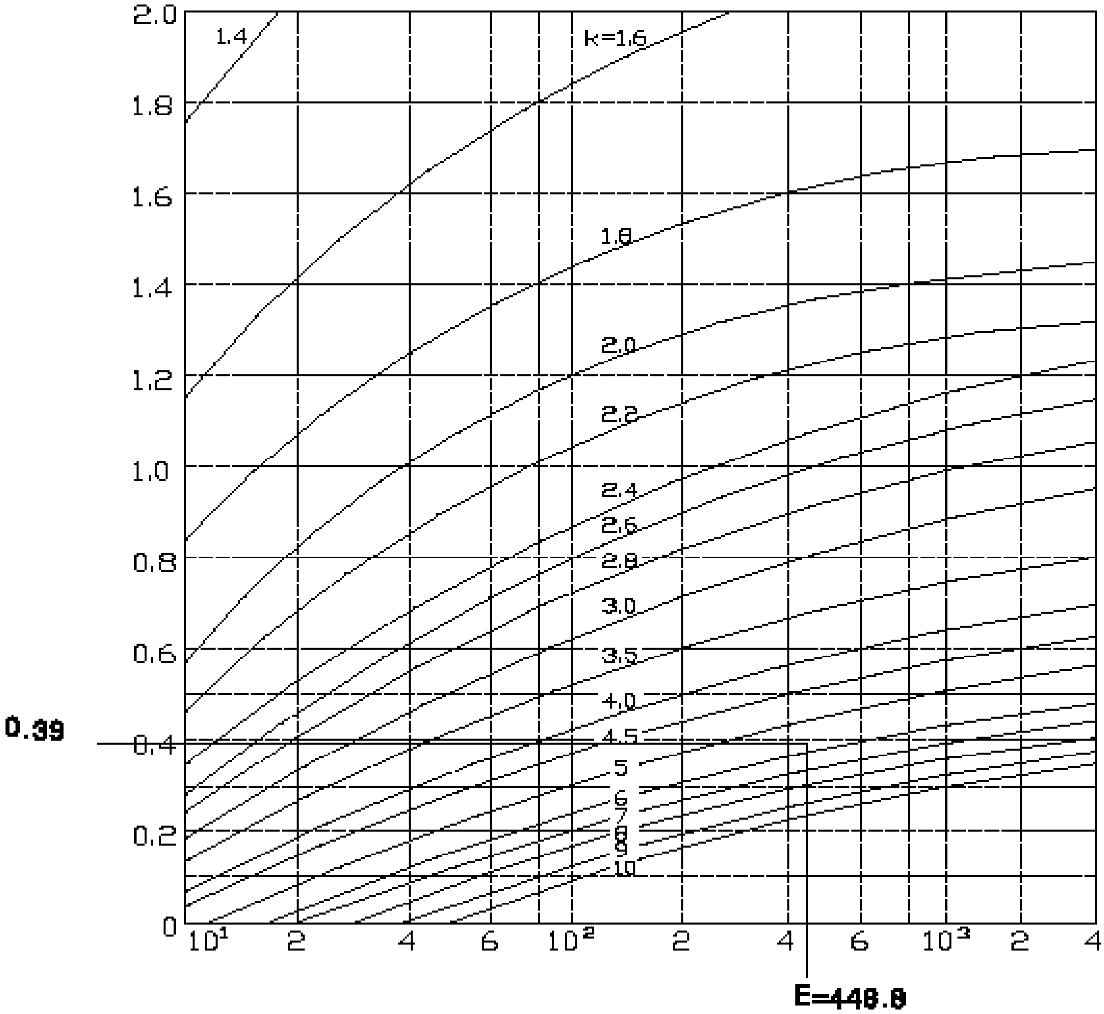
* CALCULATION FOR 1ST HOLDING

– Expansion Ratio (E)

$$E = \frac{\text{Motive Pressure (mmHg A)}}{\text{Suction Pressure (mmHg A)}} = \frac{11,400}{25.4} = \mathbf{448.8}$$

– Consumption Ratio (K)

$$K = \frac{\text{Discharge Pressure (mmHg A)}}{\text{Suction Pressure (mmHg A)}} = \frac{148}{25.4} = \mathbf{5.83}$$



– Suction Ratio Graph : α = 0.39

– Motive Suction Consuption

$$= \frac{\text{Dry Air Equivalent (kg/hr)}}{\text{Suction Ratio Graph } (\alpha)} = \frac{115}{0.39} = \mathbf{295} \text{ kg/hr}$$

DESIGN

* CALCULATION FOR 2ND HOLDING

– Weight of load

Dry Air :	31.0 kg/hr	1st Holding Ejector Load
Water Vapor :	12.0 kg/hr	Non-Condensate of the After condenser
Total Mixture :	43.0 kg/hr	
Mole Weight :	24.77	

– Suction Condition

Ls	: Load (kg/hr)	=	43.0	Weight of Load
Ps	: Pressure (mmHg A)	=	143	1st Holding Ejector Discha

– Motive Condition

Lm	: Load (kg/hr)	=	195	Motive Suction Consumption
Pm	: Pressure (kg/㎠ A)	=	15	

– Discharge Condition

Ld	: Load (kg/hr)	=	238	=Ls + Lm
Pd	: Pressure (mmHg A)	=	800	*

*** The discharge pressure has to design more than atomospheric pressure (760mmHg A), or less than the suction pressure for next stage.**

– Dry Air Equivalent

$$AE = \frac{Ls}{0.88} = \frac{43.0}{0.88} = \mathbf{49} \text{ kg/hr}$$

DESIGN

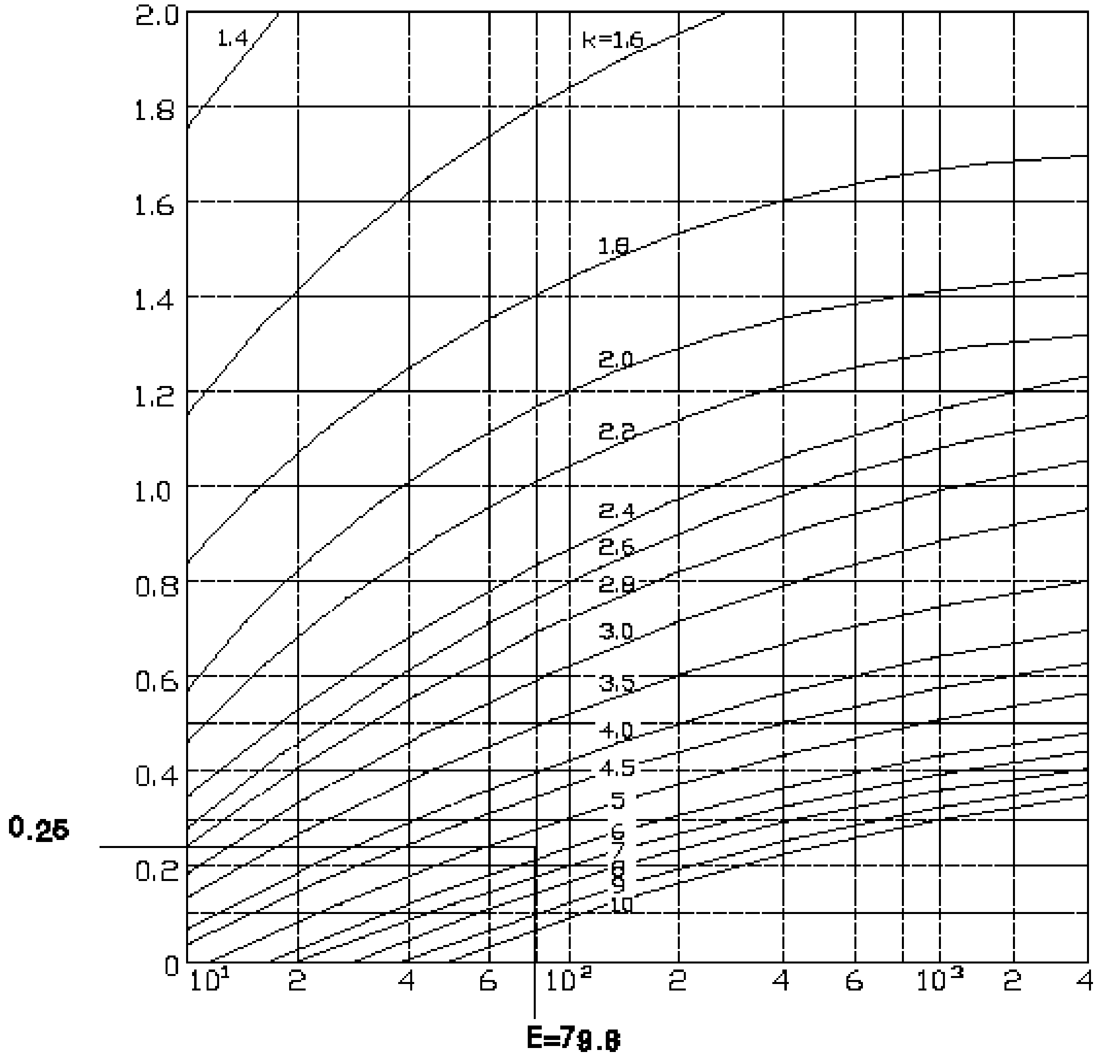
* CALCULATION FOR 2ND HOLDING

– Expansion Ratio (E)

$$E = \frac{\text{Motive Pressure (mmHg A)}}{\text{Suction Pressure (mmHg A)}} = \frac{11,400}{143} = \mathbf{79.7}$$

– Consumption Ratio (K)

$$K = \frac{\text{Discharge Pressure (mmHg A)}}{\text{Suction Pressure (mmHg A)}} = \frac{800}{143} = \mathbf{5.59}$$



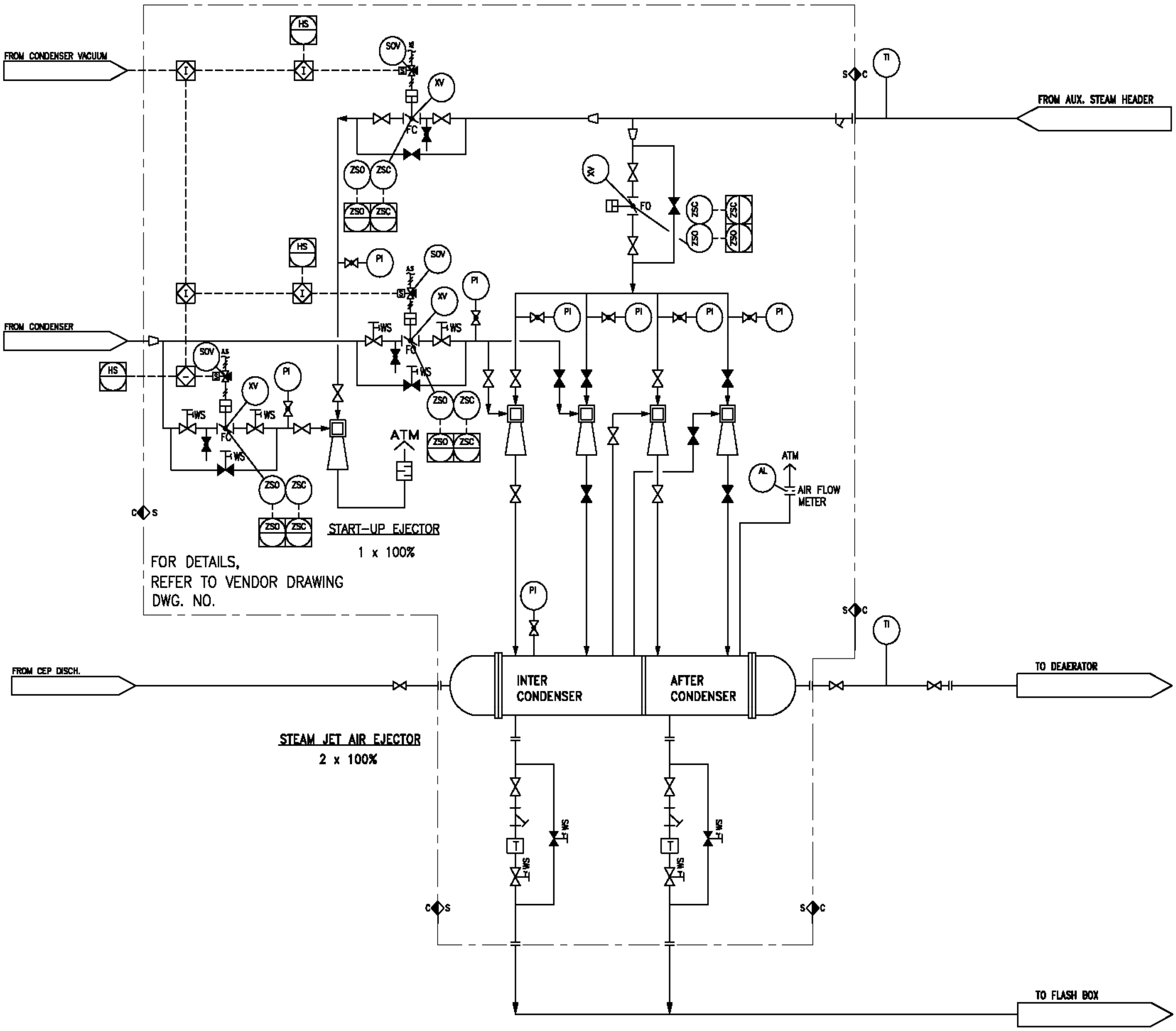
– Suction Ratio Graph : α = 0.25

– Motive Suction Consuption

$$= \frac{\text{Suction Condition Load (kg/hr)}}{\text{Suction Ratio Graph } (\alpha)} = \frac{49}{0.25} = \mathbf{196} \text{ kg/hr}$$

DESIGN

* P & I D


FROM CONDENSER VACUUM
FROM AUX. STEAM HEADER
FROM CONDENSER
FROM CEP DISCH.
TO DEAERATOR
TO FLASH BOX
START-UP EJECTOR
1 x 100%
FOR DETAILS,
REFER TO VENDOR DRAWING
DWG. NO.
STEAM JET AIR EJECTOR
2 x 100%
INTER
CONDENSER
AFTER
CONDENSER
AIR FLOW
METER
ATM

PHOTO

<u>* PERFORMANCE TEST</u>

PHOTO

* NUEVA STEAM JET AIR EJECTORS

PHOTO

* RAS-LAFFAN STEAM JET AIR EJECTORS