

Ejector

Installation, Operation, Maintenance and Manual

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SECTION I - GENERAL INFORMATION

1.1 Introduction

The purpose of an ejector is to transport a gas, liquid, powder or solid particles from one pressure level to a higher pressure level. It is easy to operate, durable and generally trouble-free because there are no moving parts.

It is to be emphasized that the ejector is probably one of the most foolproof, trouble-free pieces of apparatus that operates in any vacuum cycle. This does not mean that the apparatus can be abused beyond all limitations, nor does it mean that it can be ignored so far as inspection, maintenance and repair are concerned.

There are a few, rather simple, rules to follow in the operation and maintenance of ejector equipment and, if the operator will adhere to these rules, little or no difficulty may be expected.

1.2 Principle of Operation

Atmospheric to high pressure motive fluid passes through the motive nozzle where its pressure is dissipated in accelerating this fluid to high velocity as it exits the mouth of the nozzle. This high velocity stream of fluid issued from the nozzle mouth entrains the suction fluid. Entrainment between the motive fluid and the low pressure suction fluid causes the latter to move with the motive fluid. These two streams mix as they pass into the diffuser. The velocity profile is constantly changing and the pressure continues to rise as the discharge of the diffuser is reached.

1.3 Mechanical Description

Refer to Page 12, Figure I for a ***complete*** description of all parts for a cast ejector and two types of fabricated ejectors. There are only four basic parts of an ejector. They are:

- Motive nozzle (1)
- Motive chest (3)
- Suction chamber (5)
- Inlet / outlet diffuser (7), or (7) and (9).

The motive inlet may be flanged or welded rather than NPT as shown. The suction and discharge may have weld ends rather than flanges on fabricated ejectors only.

SECTION II - INSTALLATION

2.1 *Initial Inspection*

Inspect for shipping damage to all protective covers. If damage is evident, inspect for internal contamination and replace protective covers if the unit is going to be stored. If the unit is damaged mechanically, ***notify the carrier immediately*** and then contact Graham Corporation.

2.2 *Installation*

Sufficient clearance should be provided to permit removal of the motive chest which contains the motive nozzle that protrudes inside the suction chamber. The ejector may be installed in any desired position. It should be cautioned that if the ejector is pointed vertically upward, a drain must be present in the motive chest or in the suction piping to drain any liquid that could accumulate. This liquid will act as load until completely flashed off, thus giving a false performance indication. The liquid could also freeze and cause damage to the ejector.

The motive line size should correspond to the motive inlet size. Oversize lines will reduce the motive velocity and cause condensation when the motive fluid is a condensible. Undersized lines will result in excessive line pressure drop and, thus, potentially low pressure motive fluid to the nozzle. If the motive fluid is a condensible fluid (such as steam), the lines should be insulated. Refer to Page 12, Figure I for proper piping of the motive fluid line.

The suction and discharge piping should match or be larger than that of the equipment. A smaller size pipe will result in pressure drop, possibly causing a malfunction or reduction in performance. A large size pipe may be required depending upon the length of run and fittings present. Appropriate line loss calculations should be checked. The piping should be designed so that there are no loads (forces and moments) present that could result in damage. Flexible connections or expansion joints should be used if there is any doubt in the load transmitted to the suction and discharge flanges. If the discharge pipe is designed to exhaust to a hotwell, the pipe should be submerged to a maximum of 12" below the liquid level. If the discharge exhausts to atmosphere, the sound pressure level should be checked for meeting the requirements of OSHA standards.

A thermostatic type trap should be avoided since they have a tendency to cause a surge or loss of steam pressure when they initially open. This could cause the ejector to become unstable.

SECTION III - OPERATION

3.1 *Startup*

The ejector motive line should be disconnected as near as possible to the motive inlet and the lines blown clear. This is extremely important on new installations where weld slag and chips may be present and on units that have been idle where rust and scale particles could exist. These particles could easily plug the motive nozzle throats. If a strainer, separator and/or trap is present, they should be inspected and cleaned after the lines are blown clear.

If condensers are present, check to insure that the vapor outlet of the aftercondenser and condensate outlets are open and free of obstructions. Be sure the cooling medium is flowing to the condenser(s). (Refer to separate manual, e.g. Shell and Tube Heat Exchanger, Barometric Condenser, In-Line Inter/Aftercondenser or Heliflow for proper operation.) Refer to Pages 13, 14 and 15, Figures II, III, and IV for nomenclature for various stages and condensers.

Open all suction and discharge isolating valves if present. If the unit has dual elements with condensers present, make sure the condenser has been designed for both elements operating. If the condenser has been designed for one element operating, open the suction and discharge valves to one element only (isolate other element).

Fully open the motive valve to the 'Z' stage(s). For optimum performance during an evacuation cycle, the motive valves should always be open starting with the 'Z' stage and proceeding to the 'Y,' 'X,' etc. stages. If a pressure gauge is present near the motive inlet, check the reading to ensure the operating pressure is at or slightly above that for which the unit is designed. The motive pressure gauge should be protected with a pigtail if the motive fluid is a high temperature gas or condensible fluid. This is to insure protection of the internal working parts of the gauge. The design operating pressure is stamped on the ejector nameplate.

In the case of a system having twin 100% ejector elements, all four ejectors can be operated at start-up to reduce the time required to evacuate the system. After the system has been evacuated to the normal operating pressure, one of the ejector elements (one Y stage and one Z stage) can be taken out of service to conserve motive steam usage. This should be done by closing the valves in the following order:

- 1) 'Y' stage (first stage) suction.
- 2) 'Y' stage (first stage) motive inlet.
- 3) 'Y' stage (first stage) discharge.
- 4) 'Z' stage (second stage) suction.
- 5) 'Z' stage (second stage) motive inlet.
- 6) 'Z' stage (second stage) discharge (if present).

Twin element, two stage ejectors with inter/aftercondensers are generally equipped with relief valve(s). The relief valves are nominally set at 15 PSIG. If the operating procedures for startup or shutdown are not followed exactly, the ejectors could be exposed to full operating motive pressure and they are normally not designed to withstand this pressure. The relief valves protect the ejector in the event the motive steam is inadvertently turned on when the isolating valves are closed. The ejectors may be designed for the motive pressure if relief valves are not present, but it is suggested the outline drawing be checked for notes pertaining to this feature or consult the factory.

3.2 Shutdown

There are two procedures to be considered when shutting down:

Method A: If it is desired to maintain the vacuum upstream of first stage ejector (an isolating valve has to be present at suction) rather than allowing pressure to rise to atmospheric pressure, the valves should be closed in the following order:

- 1) Close first stage suction valve.
- 2) Close first stage motive inlet valve.
- 3) Close first stage discharge valve.
- 4) Close second stage suction valve.
- 5) Close second stage motive inlet valve.
- 6) Close second stage discharge valve (if present).

Note: If there are more than two stages, STOP AT STEP 5 and continue to repeat steps 3, 4 and 5 for each additional ejector present and ending with step 6 on final stage. If the system contains an isolating valve at the first stage suction only, the procedure would be to close this valve and then either shut off the motive to all ejectors at once or shut them off by stages, starting at the first stage. When all motive valves have been shut off, the cooling medium may be turned off also. If the unit is going to be shut down for a short period of time to service the ejectors or for some other reason, it is not necessary to shut off the cooling medium. Energy savings should be considered when making this decision. If the unit is going to be down and freezing of the cooling medium is possible, then measures must be taken to prevent freezing or the unit drained as much as possible to prevent damage.

Method B: If it is not required to maintain a vacuum upstream of first stage ejector, the valves should be closed in the following order:

- 1) Close main motive valve to all the ejectors or close the motive valve(s) to each individual stage, starting at first stage and continue on to second, etc.
- 2) The cooling medium may be turned off as explained in preceding paragraphs.

3.3 *Switching Ejector Elements*

Should it become necessary or desirable to shift from one two-stage element to another while the unit is in operation, proceed as follows:

- 1) Open discharge valve of the standby second stage ejector (if provided).
- 2) Open second stage motive valve.
- 3) Open second stage suction valve. When this has been accomplished, this standby second stage ejector begins to take suction from the intercondenser along with the other second stage element.
- 4) Open first stage discharge valve on standby element.
- 5) Open first stage motive valve.
- 6) Open first stage suction valve. At this point, both two stage elements are in parallel operation.

The operating element can now be secured by closing the valves as follows:

- 1) Close first stage suction valve.
- 2) Close first stage motive valve.
- 3) Close first stage discharge valve.
- 4) Close second stage suction valve.
- 5) Close second stage motive valve.
- 6) Close second stage discharge valve (if provided).

SECTION IV - TROUBLESHOOTING

4.1 *General*

Malfunctions of ejectors can be difficult to analyze unless a step-by-step procedure is followed. Through the process of elimination, the problem area can be located and corrected.

There are basically only four main areas that will cause an ejector to malfunction and these are:

- 1) Motive fluid conditions and properties different than designed.
- 2) Overloading conditions.
- 3) Discharge conditions.
- 4) Mechanical damage or wear.

4.2 Motive Fluid Conditions

With all ejectors operating, check the motive steam pressure at the steam inlet to each stage. Do not *assume* the pressure measured at one will be the same at another stage since an obstruction causing pressure drop could be present. The motive pressure check should be performed with a calibrated gauge (make sure the gauge is protected with a pigtail.). A pressure gauge with the appropriate scale should be installed on the motive inlet of each stage (immediately prior to the steam chests). It is essential that the motive pressure not be less than the design pressure at any time during operation. Motive pressures in excess of the design pressure may also be detrimental to the operation. If this pressure exceeds 120% of the design, a pressure reducing station should be utilized. Normally the excessive motive pressure will waste motive fluid and tend to choke the diffuser throat, decreasing the capacity of the ejector. Instances of non-condensable overload, however, can be compensated for by higher than design motive pressure. Therefore, excessive motive pressure may not always appear to be detrimental - it may indicate a problem exists elsewhere.

The motive, if a condensible fluid, should be 100% quality or slightly superheated. Ejectors operating at a suction pressure greater than approximately 7 mmHgA will function on approximately 1% moisture (99% quality). Highly superheated motive steam will act as if low steam pressure is present (due to the higher specific volume). If there is any doubt of the quality of the steam, install a steam separator of the proper size and type in the steam supply line as close to the ejector motive inlet as possible. The separator serves the purpose of removing the moisture by utilizing a centrifugal scrubbing action. ***The separator must be installed in a vertical position for sizes 2" and smaller and horizontal or vertical for sizes 2-1/2" and larger.*** The separator should include a ***bucket type trap*** or a blow-down valve to permit the constant drainage of any condensate. (Note: Do not use a thermally actuated trap.) If a blow-down valve is utilized, it is only necessary that this valve be cracked open until a small wisp of steam is blown to atmosphere. All lines should be fully insulated for proper operation and for personnel protection. Moisture in the motive steam can cause erratic operation, act as load to the ejector, and result in erosion and pitting of the steam nozzle and diffuser. The motive fluid may contain a contaminant, resulting in a buildup in the motive nozzle as well as other parts of the ejector. In addition, small particles can become lodged in the motive nozzle throat. The motive nozzle may be checked for pluggage by closing the motive steam valve tightly to insure that there is not any high pressure motive present in the motive line. Remove the inspection/clean-out plug (if present) and with the use of a flashlight, inspect the throat. A properly sized rod or reamer may be inserted into the opening to attempt to dislodge or clean any material from the throat area. This same rod or reamer may be used for checking for wear (refer to Section 4.5). The motive chest, with nozzle intact, may be unbolted and removed for a thorough inspection.

4.3 Overloading Conditions

Overloading can be due either to excessive process loads, air in-leakage, and/or the load at a temperature higher than design. It must be determined if the source of the overload is upstream of the first stage ejector or within the ejector system. This is done by isolating the first stage ejector from the remainder of the vacuum system upstream. A blank-off plate inserted at the suction of first stage is the easiest method. (Note: Even if an isolating valve is present, a blank-off plate should be used since valves may leak.)

At zero load, the ejector will evacuate to shut-off pressures of approximate values shown below for various number of stages:

Single stage unit -----	50 mmHgA (may be unstable)
Two stage unit-----	4 to 10 mmHgA
Three stage unit -----	0.8 to 1.5 mmHgA
Four stage unit -----	0.1 to 0.2 mmHgA
Five stage unit-----	0.01 to 0.02 mmHgA
Six stage unit -----	0.001 to 0.003 mmHgA

The above shut-off pressures are only approximate and will vary with each particular ejector. However, if the blank-off test indicates the ejector is operating in a stable condition at its approximate shut-off pressure, then it can be assumed that the ejector most likely will operate satisfactorily along with its entire performance curve. If this is the case, further troubleshooting would then be required on the vacuum system or upstream of ejector.

If the shut-off pressure is not obtained or is unstable, then the troubleshooting should be confined to the ejector system. A hydrotest for checking air leakage is recommended, however, it should be verified that the system is designed to carry the extra pressure and weight of the water required to fill the system. There are other methods, such as a Halide leak detector, that are acceptable. Another method, while the system is operating and under vacuum, is to use ordinary shaving cream applied to all joints, etc. If a leak is present, it will suck the cream into the leaking area and is easily observed. If there are intercondensers present in the system, overloading of the downstream ejectors can occur due to low cooling fluid flow, high inlet cooling fluid temperature and/or fouling. Refer to Auxiliary Operation, Maintenance & Installation Manual for the type of condenser present.

4.4 Discharge Conditions

Pressure exceeding the design at the discharge of any of the ejectors may be a cause of poor performance. The last stage ejector should be checked first. If a calibrated pressure gauge cannot be located directly at the ejector discharge, the discharge piping should be disconnected and the ejector allowed to exhaust directly to atmosphere.

The other ejectors upstream of intercondensers should also be checked for back pressure greater than design. The ejector must remain bolted to the condenser. An absolute pressure gauge reading should be taken directly at discharge of ejector, before it enters the condenser and compared to the design. If higher than design, check for an obstruction or buildup at the inlet to the condenser or piping leading to the condenser, buildup inside the condenser, fouled condenser, insufficient cooling fluid or cooling fluid inlet temperature higher than design.

4.5 Mechanical Damage and Wear

The final step would be to check the internals for damage or wear. Both the motive nozzle and diffuser throats should be checked and if the wear exceeds 7% of the original design area, the parts should be replaced. The steam nozzle and diffuser interior should be smooth and clean. If any scale, product build-up or roughness is present on inlet diffuser internals, this should be removed by an acceptable method. The tapered sections of both the nozzle and diffuser should be free of pitting, lines, and/or ridges. **CAUTION:** The motive nozzles should be handled very carefully to insure that the nozzle mouth or threads are not damaged. It is important to inspect the motive nozzle mouth for any indentations or other irregularities. A new nozzle should be installed if the existing one is damaged.

Visible lines on the internal section of the motive nozzle extending from throat to mouth, even if they do not seem to be worn into the metal, usually indicate that there is wet steam present. Motive nozzle internals may be cleaned, but nozzle replacement is recommended. Corrective action should be taken to improve motive quality.

The threads on the motive nozzle, extension or steam chest should be checked for wire-draw and other damage. This is a source for high pressure motive leakage to the inside of the ejector, causing an artificial load which, in turn, increases in suction pressure. **NOTE: Steam nozzles and nozzle extensions must be securely tightened to prevent leakage (suggested torque of 150 ft./lbs.).**

SECTION V - OPERATOR'S MAINTENANCE

First 15 and 30 Days (for new installations): Blow out steam strainers while units are in operation.

Every 3 Months: Check steam pressure and other utilities.

Every 12 Months: Remove, clean, and inspect strainers if present. Check nozzle and diffuser internals. Inspect relief valves, if present. NOTE: Refer to inspection points listed in auxiliary equipment manuals such as condensers.

SECTION VI - REPAIR AND REPLACEMENT ORDERS

When it is necessary to obtain spare parts, please address your communication to:

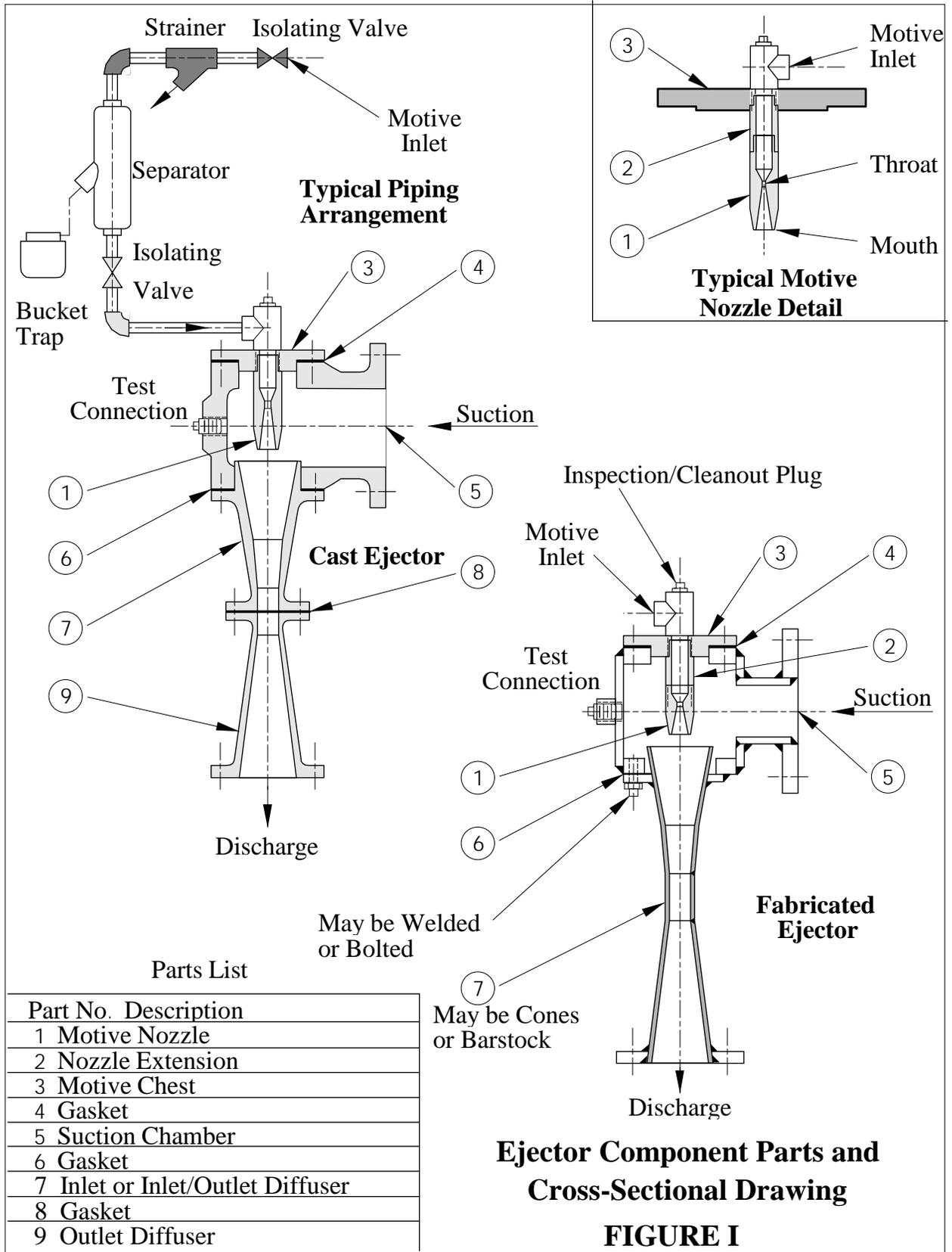
GRAHAM CORPORATION
20 Florence Avenue
Batavia, New York 14020

Telephone: 585 / 343-2216
Spare Parts: 800 / 828-8150
Fax: 585 / 343-1097
E-MAIL: spares@graham-mfg.com
WEBSITE: <http://www.graham-mfg.com>

IMPORTANT - The following information should be given in order to identify the spare parts required:

1. Serial number of unit (stamped on nameplate),
2. Name or description of part required,
3. Method of shipment (i.e. freight, express, etc.).

Graham Corporation presents the information in this manual as good engineering practice. We cannot be held responsible for any damage to equipment that may result from mal-operation nor for any personal injuries should they occur during normal or abnormal operation.



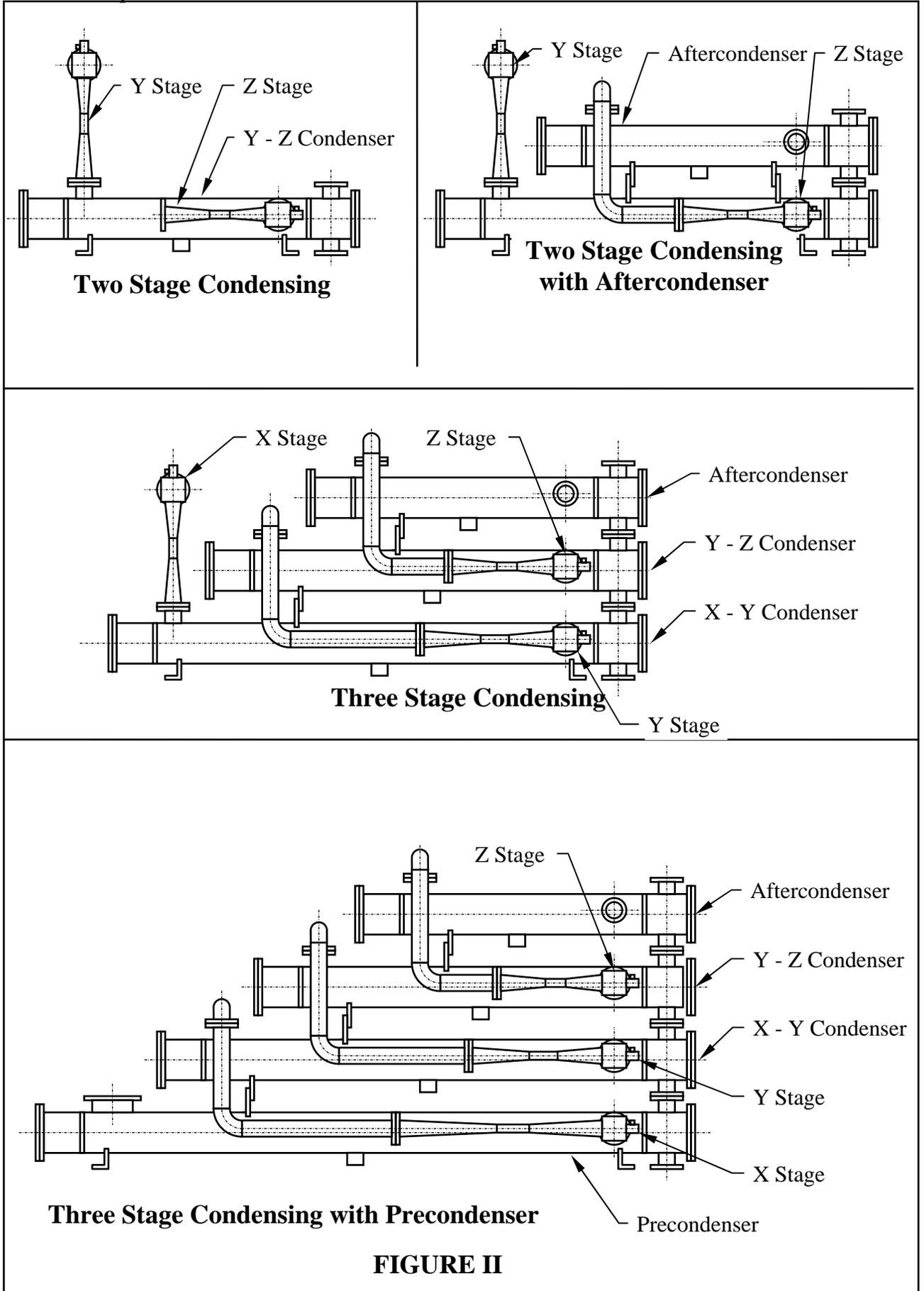


FIGURE II

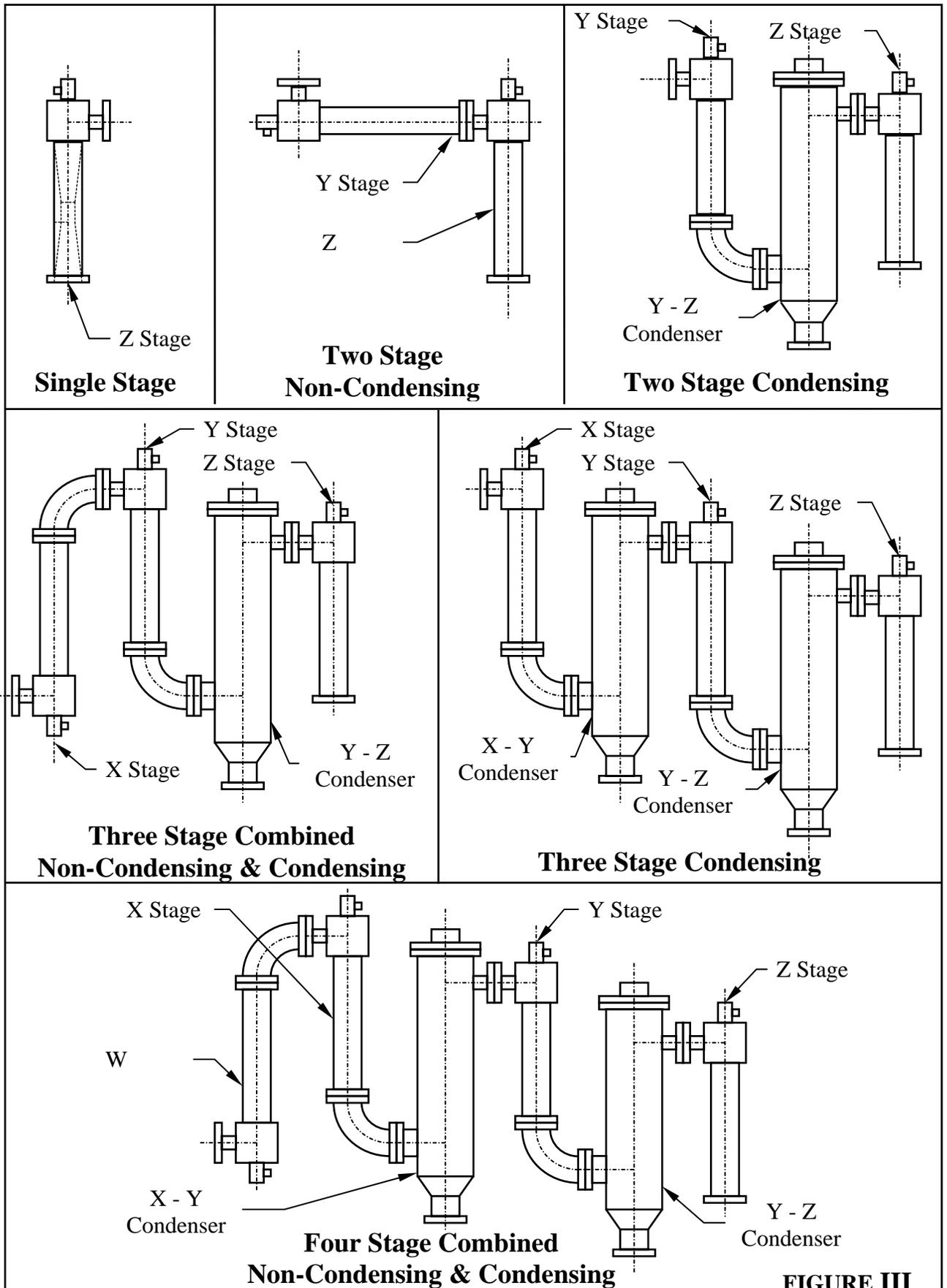


FIGURE III

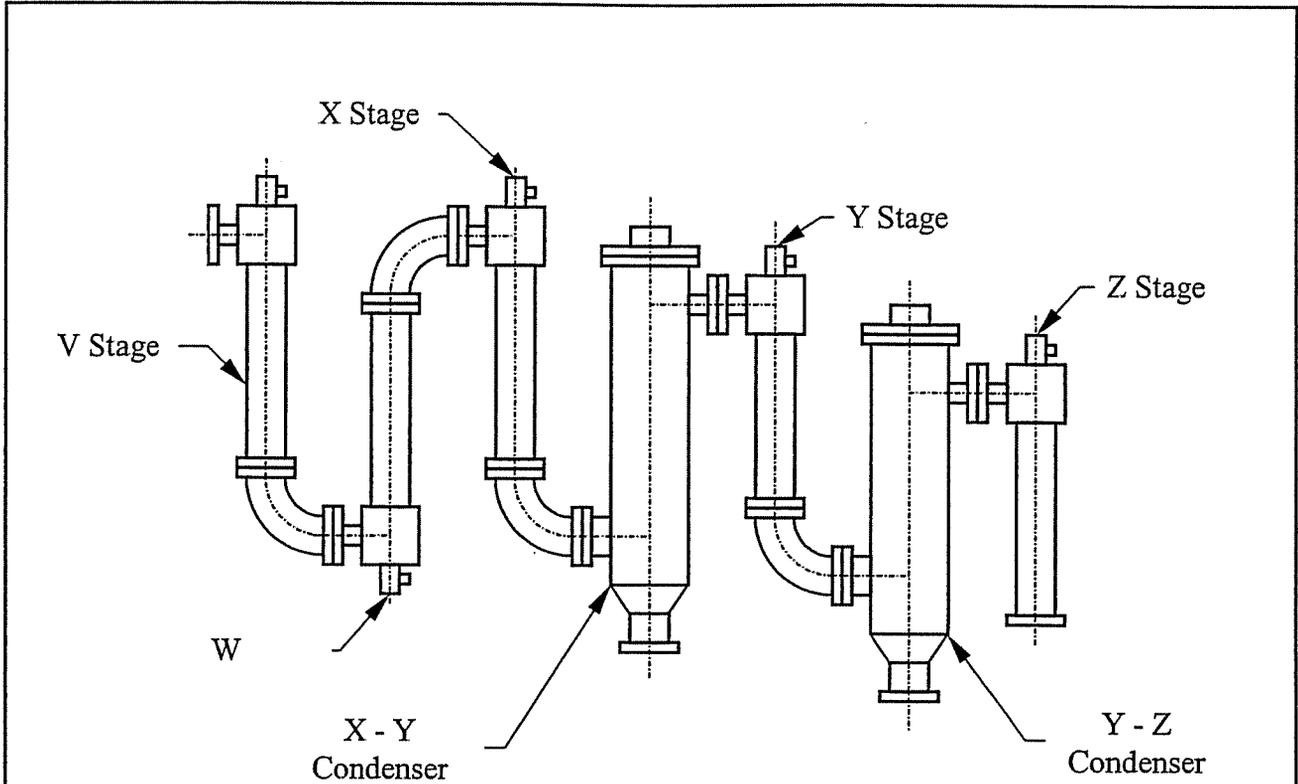
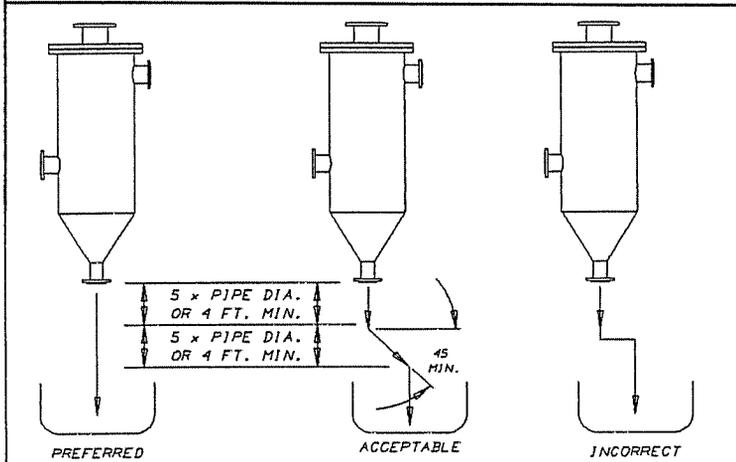
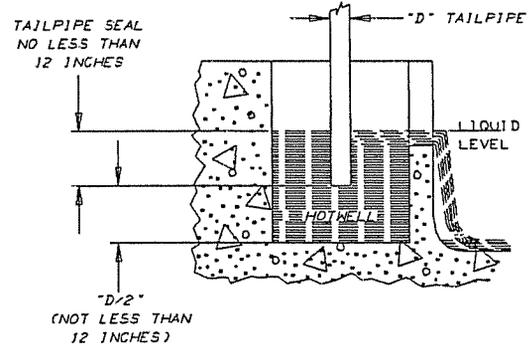


FIGURE IV, Five Stage Combined Non-Condensing & Condensing



Tailpipe Arrangement
 Tailpipe arrangement for direct contact or surface condensers.
 Note: Horizontal pipe runs to be avoided wherever possible.

FIGURE V



Hotwell Design
FIGURE VI

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