The Right Connection®

Petroleum Tank Truck Industry Bottom-Loading and Vapor Recovery

An overview on the development of bottom-loading and vapor recovery in the petroleum tank truck industry.

By: Robert Koeninger, General Manager of Dixon Bayco Division

CONTENTS

INTRODUCTION

In the drive to improve workplace safety and lower operating costs, North American oil companies partnered with the transportation industry to develop the concept of bottom-loading petroleum tank trucks. Starting in the 1950s, the concept led to an industry-wide adoption of a new tanker product: a valve that permitted both loading and unloading through a common valve located at the bottom of the tanker. This valve has a special nose design, which, along with a mating dry break coupler (on the terminal loading arm), allows for the fast, safe connection, and transfer of petroleum from the terminal to the tank truck.

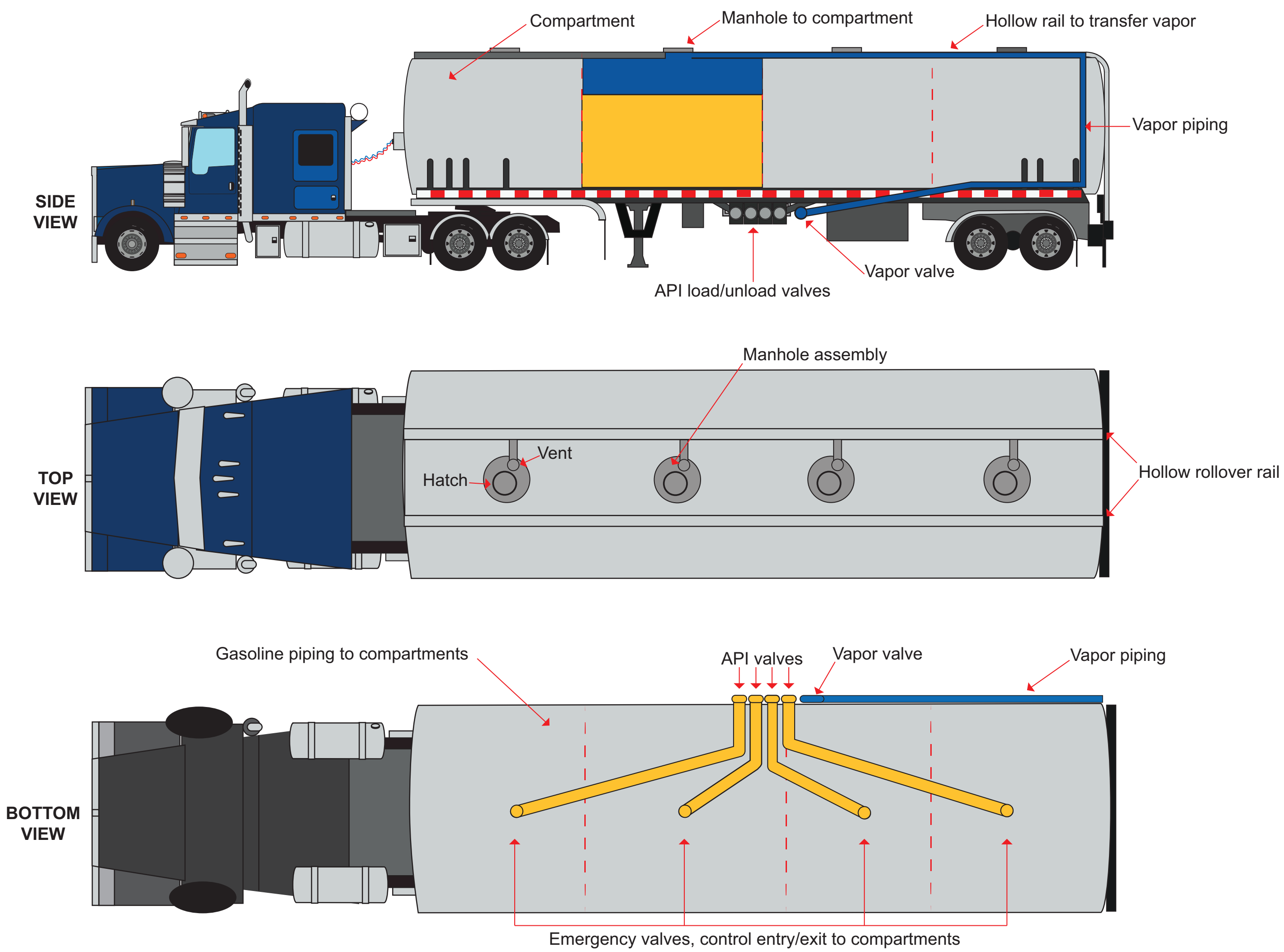
The advent of bottom-loading, combined with other tank truck improvements, made possible entirely new systems for the containment and collection of petroleum vapors. Petroleum vapors were previously exhausted to the atmosphere when loading and unloading tank trucks. This vapor recovery ability became vital as the U.S. Clean Air Act and similar legislation worldwide demanded lowering of airborne pollutants to protect the environment.

PETROLEUM TANK TRUCK BOTTOM-LOADING AND VAPOR RECOVERY

Illustration A illustrates typical tank truck construction. Petroleum tankers are usually divided into compartments, each of which can carry a different grade of fuel. An emergency valve at the bottom of each compartment controls the entry and exit of petroleum to/from the compartment. Piping connects the emergency valve to the bottom-loading API valve (for loading and unloading).

Manholes at the top of each compartment typically include a hatch for inspections or top-loading, and a compartment vent, which is connected to the vapor plumbing.

Illustration A: Typical Petroleum Tank Truck Construction



TRADITIONAL TOP-LOADING

Many parts of the world still employ traditional top-loading technology to fill petroleum tank trucks. These loading terminals typically have an elevated gantry, which allow operators to walk on top of the tank to open the manhole and drop fuel into each compartment (see Illustration B on page 6).

When unloading at the service station, drivers are often required to climb on top of the tanker and open the compartment manholes to:

1. Measure the drop with a dip stick
2. Assure the station operator of a full load
3. Allow air into the compartment when dropping fuel

The manholes are subsequently closed once the discharge is completed. Manholes with pneumatic vents or use of mechanical vents are often employed to eliminate the need to have operators on top of tankers opening and closing manholes.

PROBLEMS ASSOCIATED WITH TOP-LOADING

As shown in Illustration B (page 6), top-loading of gasoline generates considerable turbulence as well as venting of fumes to the atmosphere. The following list of problems associated with top-loading may be minimized by bottom-loading systems.

1. Static/dynamic sparks: Top-loading is prone to excessive turbulence. Splashing and the turbulent flow of petroleum can cause static electricity build-up (even when tankers are grounded). In addition, operators scrambling or walking on tankers can accidentally scrape or strike the tanker and discharge a spark. Both static or dynamically generated sparks are extremely dangerous, and, when combined with gasoline vapors, can cause catastrophic explosions.

2. Operator safety: Operators have fallen from the top of tankers with grave consequences. Top-loading operators are also exposed to gasoline fumes, which can cause health problems. Today some jurisdictions have prohibited or restricted the operators' presence on the top of the tank truck during loading and unloading.

3. Product contamination: With compartment manholes open during top-loading, the opportunity exists for rain, snow, and wind-blown dirt to contaminate the product. Aircraft fuels are particularly sensitive to minute forms of contamination. Pens, screwdrivers, and cigarettes are items that have accidentally been dropped into manhole compartments causing contamination, damage, and malfunction of emergency valves and downline equipment.

4. Time loss: Typically, top-loading permits only one compartment to be filled at a time. With bottom-loading, multiple compartments are loaded simultaneously. Faster loading reduces the time the tank truck is waiting at the terminal and greatly improves loading and delivery efficiency.

Illustration B: Petroleum Tank Truck Top-Loading at Terminal

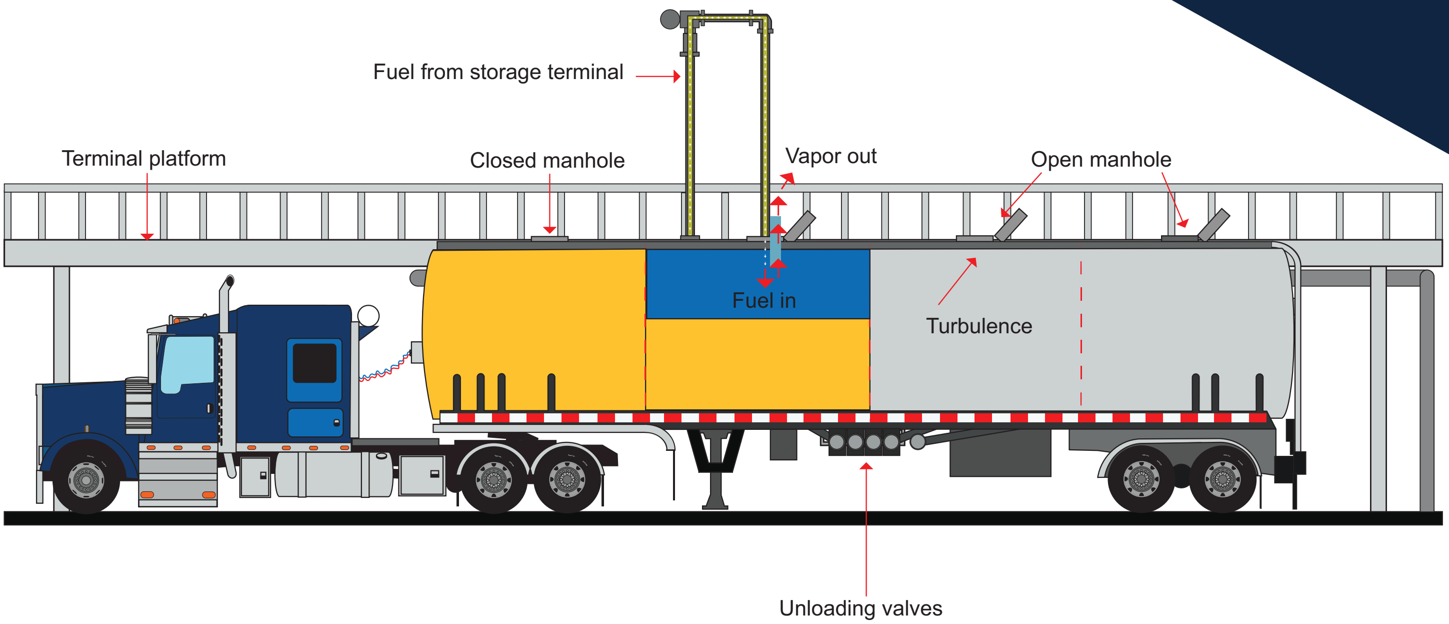
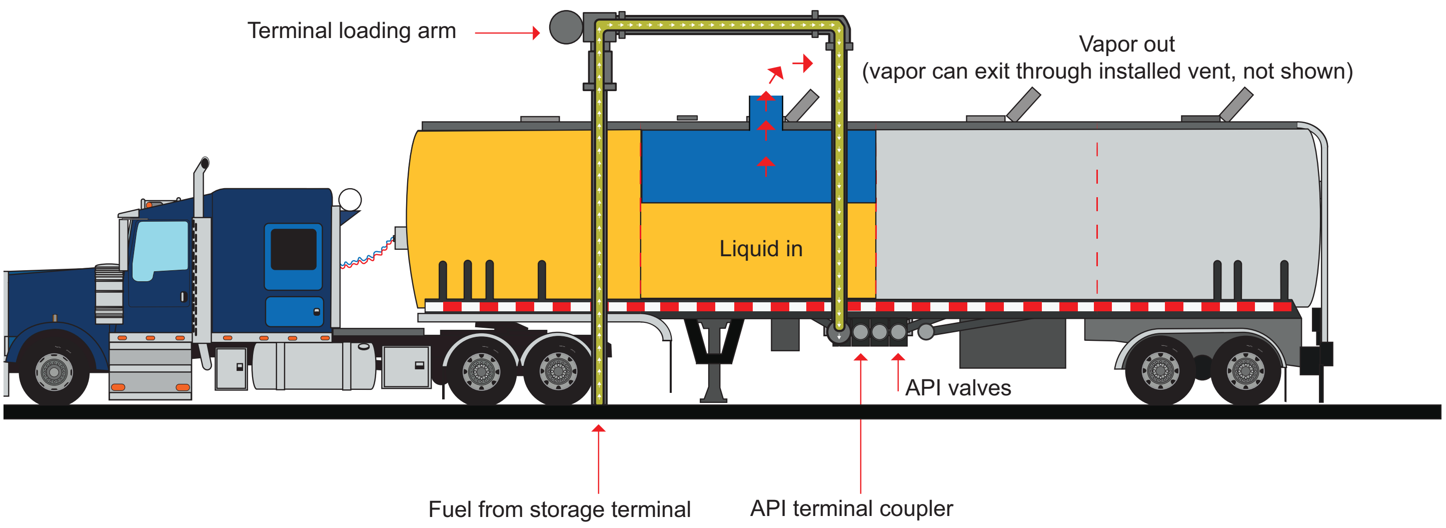


Illustration C: Petroleum Tank Truck Bottom-Loading at Terminal (no vapor recovery)

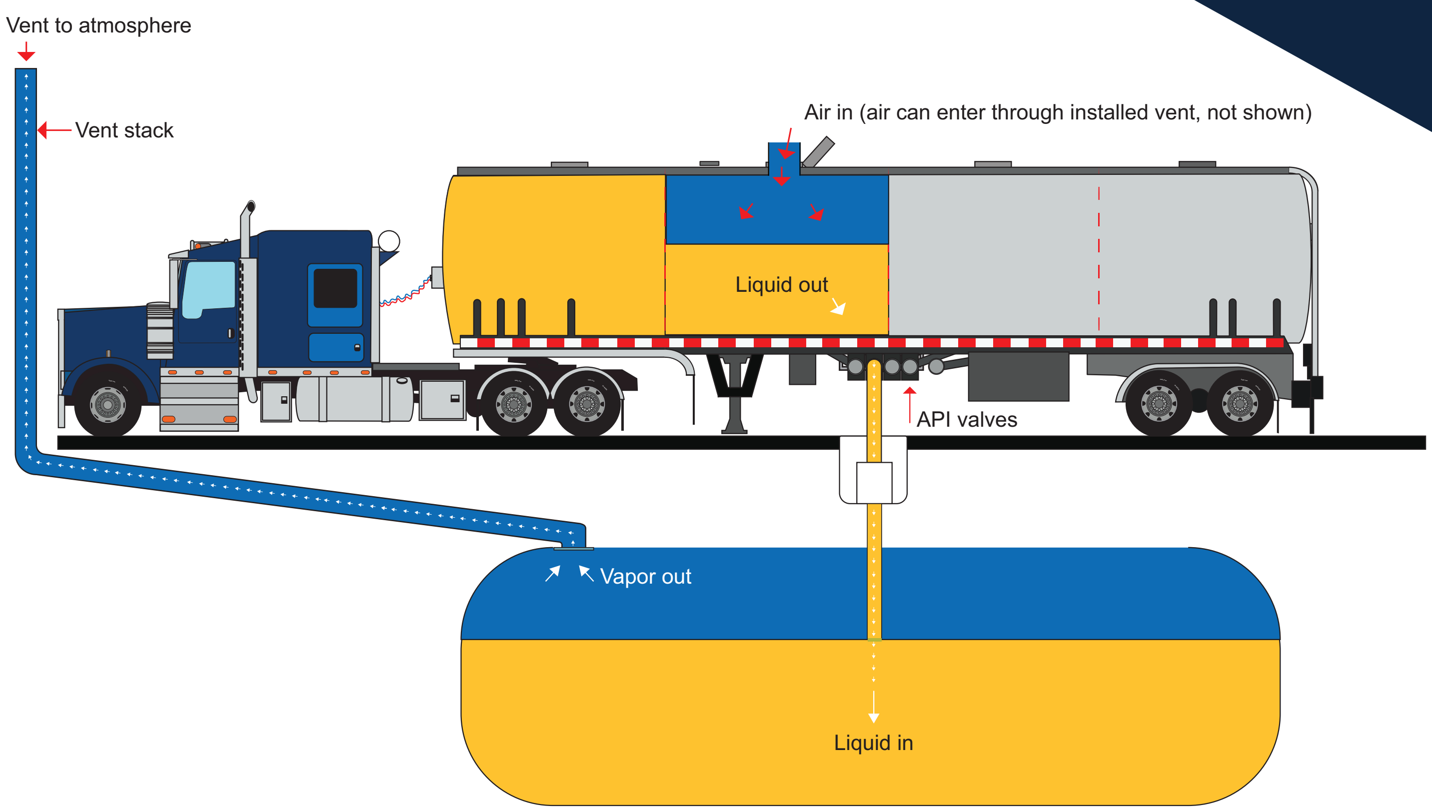


THE BOTTOM-LOADING PROCESS

Illustration C (above) shows the typical bottom-loading systems which were commonly applied prior to the introduction of vapor recovery.

The key to bottom-loading is the API valve, which was developed by the oil and transportation industry through participation in the American Petroleum Institute (API). This cooperative effort has resulted in a common specification for loading valves, as well as a standardization of coupling equipment at the petroleum terminals (see Illustration E on page 8). The API valves are placed low on the tanker and connected by piping to each compartment. There is one API valve

Illustration D: Petroleum Tank Truck Droppping Fuel at Service Station
(no vapor recovery)



per compartment. Petroleum is pumped through the loading arm system at the terminal, via the API valve, piping, and emergency valve, and into the tanker compartment. An emergency valve is located at the bottom of each compartment, which controls the entry and exit of petroleum. Bottom-loading results in fast, smooth flow filling of the compartment, with minimum turbulence. Gravity unloading of each compartment is accomplished by connecting a drop hose from the API valve to the underground tank collar, then manually opening the emergency valve and API valve to drain the compartment.

The API valve is a spring-loaded poppet valve with a special coupling nose design and a mounting flange. At the terminal, a loading arm with a special mating coupler attaches to and opens the API valve. This “dry break” style terminal coupler is designed to minimize leakage of petroleum when connecting or disconnecting (see Illustration E on page 8).

By far the most popular style of API coupler is the load/unload model, which has a handle. The handle opens the API poppet at the service station and allows for gravity unloading of the compartment.

The second style (no handle) is activated only at the terminal by the dry break API coupler during loading (this load-only valve is passive when unloading). Unloading will typically be done through a second valve such as a faucet or butterfly valve, in conjunction with "Y" shaped plumbing or a special "Y" valve. Load-only APIs are also used with manifold systems.

Illustration E: API Valve and API Coupler Mate at Terminal

API valve and API coupler mate and lock together, allowing terminal to pump petroleum through the valve into the tank truck

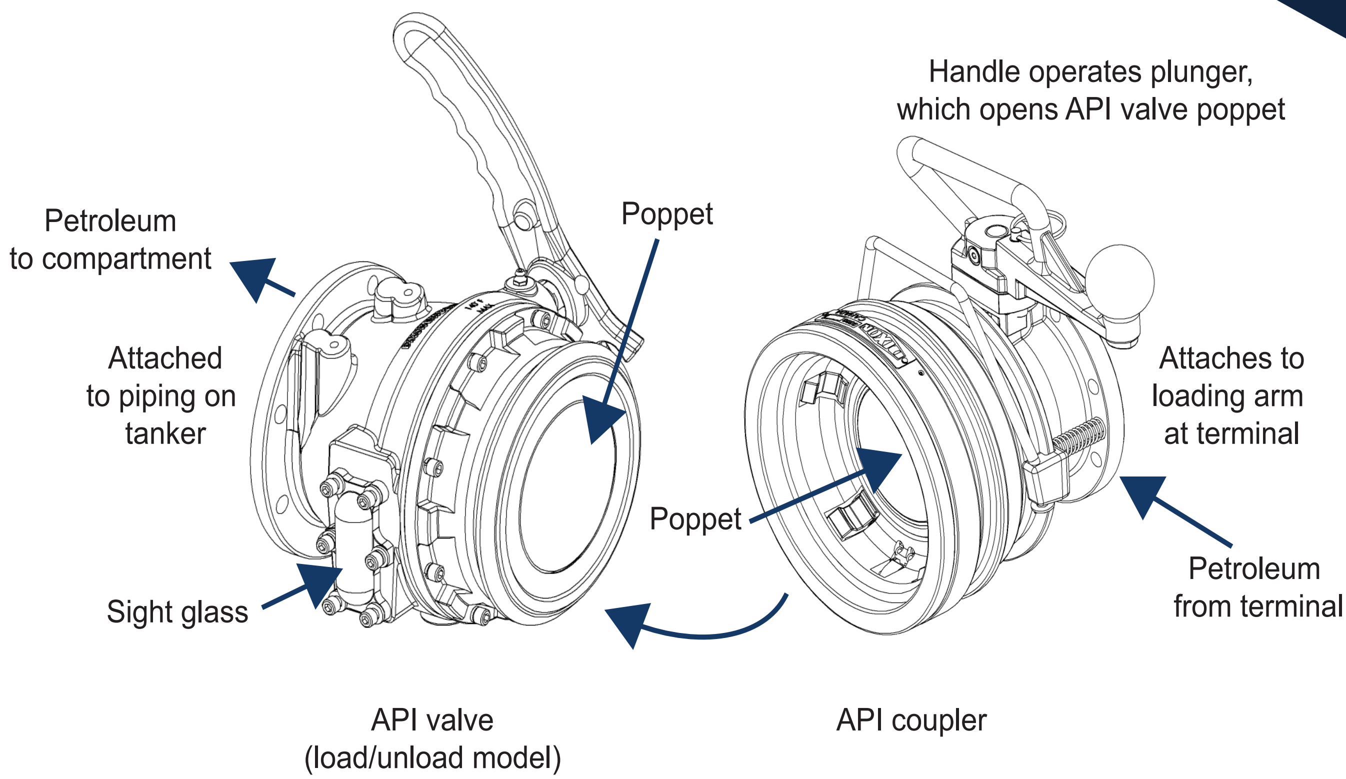


Illustration F: API Valve Connection to Drop Hose at Service Station

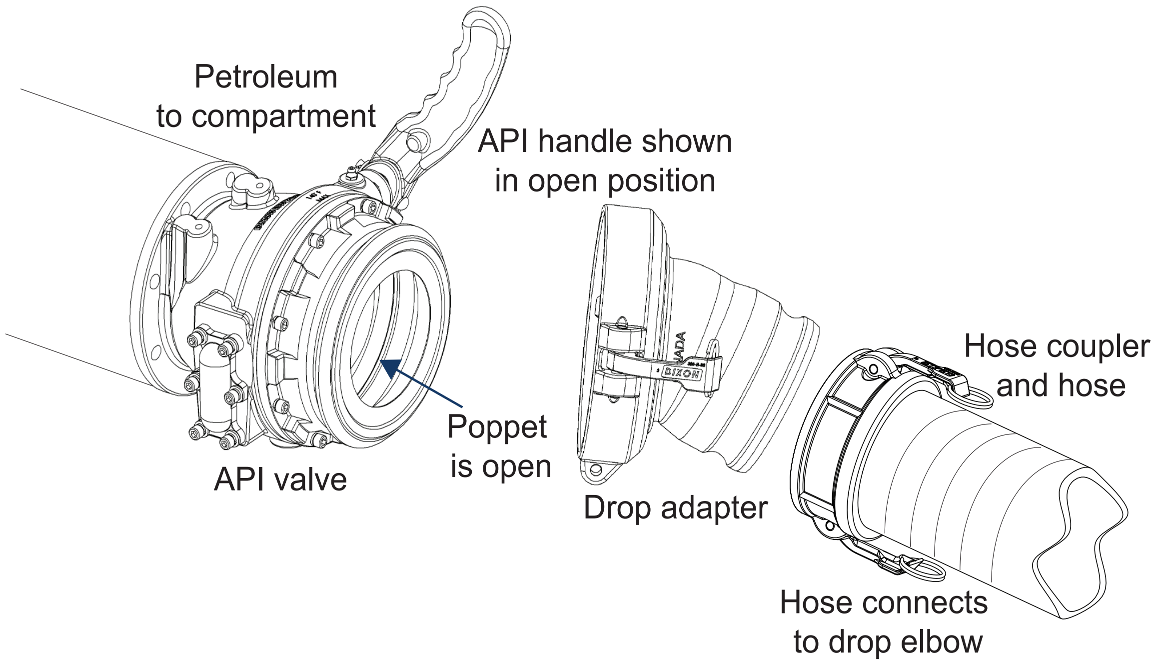
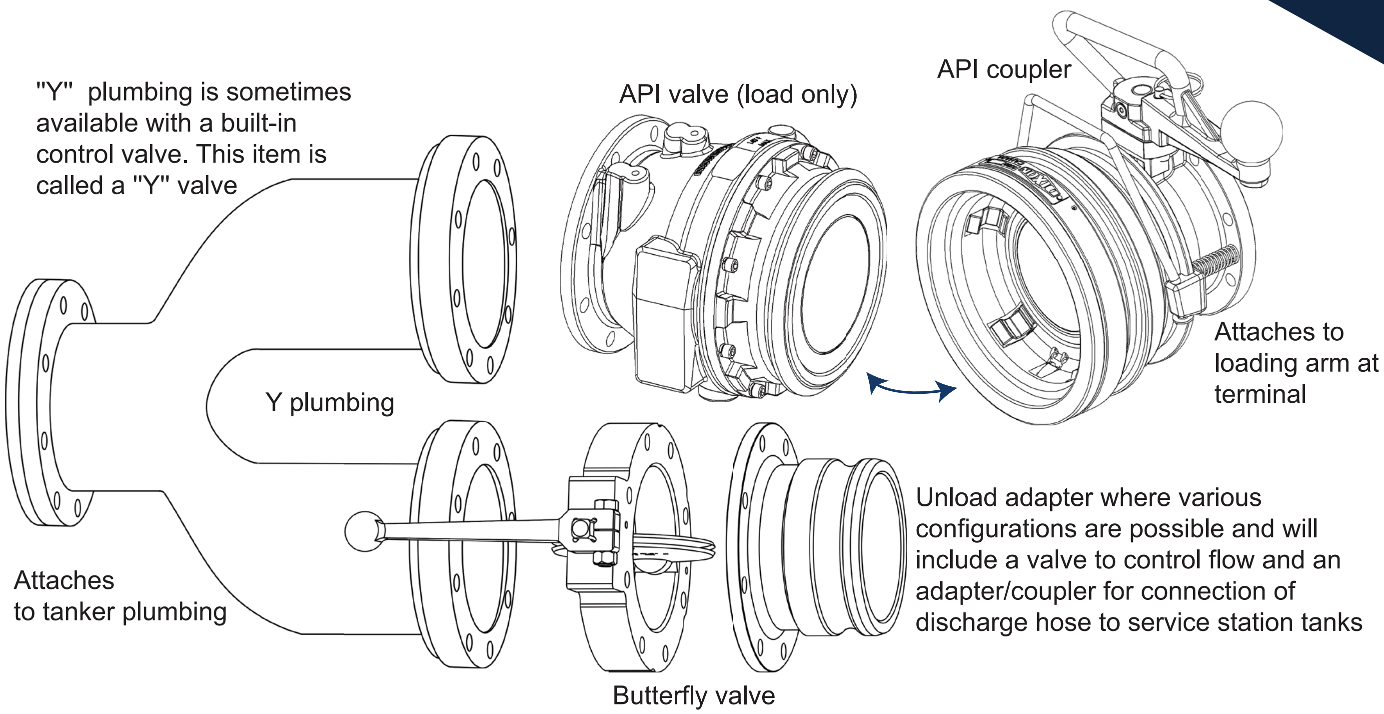


Illustration G: Application of Load-Only API Valve

Typical “Y” plumbing with load only API



VAPOR RECOVERY

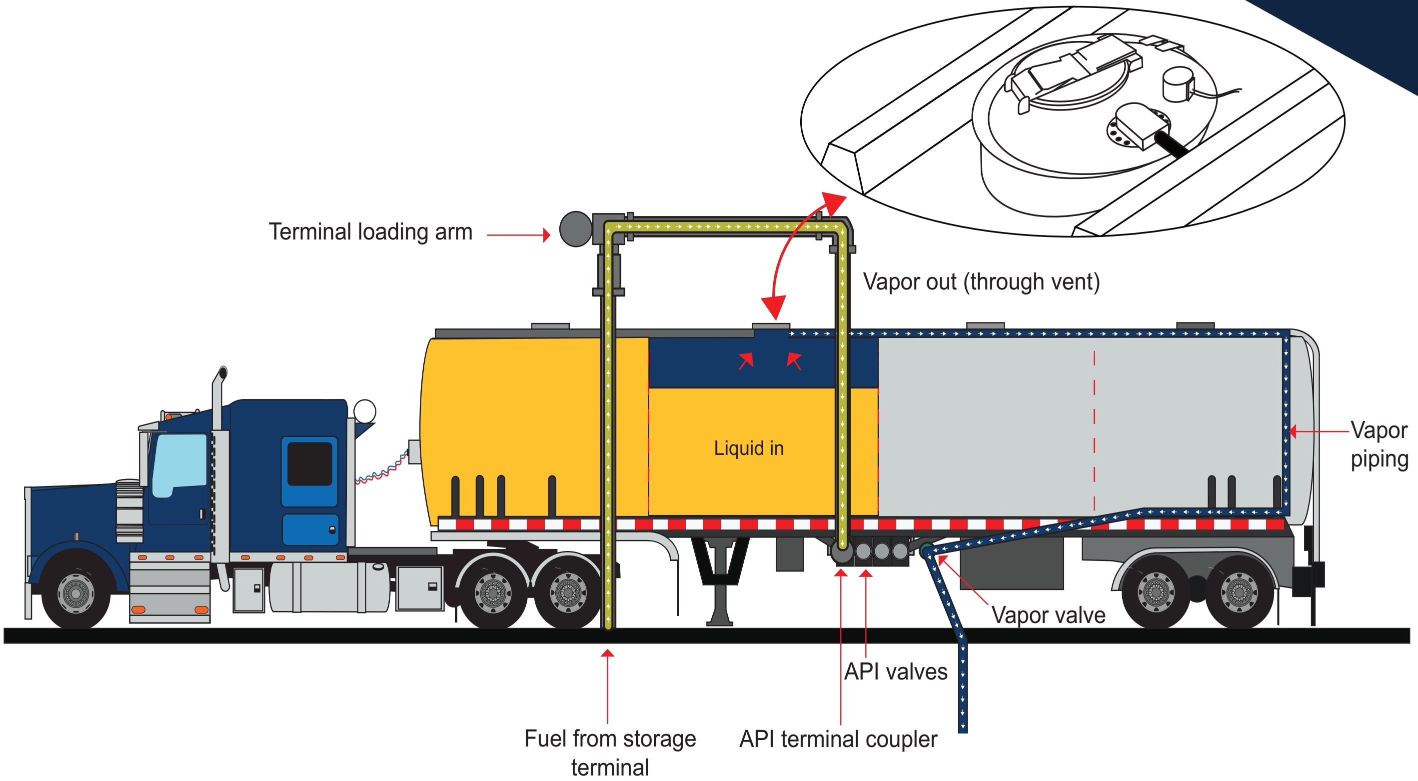
The U.S. Clean Air Act legislated major reductions of atmospheric hydrocarbon pollution. Studies have shown that up to 95% of emissions from the transportation of petroleum could be contained for recycling. As a result, the petroleum industry began to seriously examine gasoline vapor emissions and controls. Although attempts have been made to develop top-loading vapor recovery systems, the advent of bottom-loading provided superior vapor recovery technology. Today, bottom-loading vapor recovery technology dominates and has been applied worldwide.

Vapor recovery involves the prevention of gasoline vapors escaping to the atmosphere during the loading and unloading process. This is called "stage 1 vapor recovery". It requires that vapors be collected from underground service station tanks and transported to the terminal for processing. The introduction of stage 1 vapor recovery requires modifications to the service station, tank trailer, and terminal equipment. Modifications include a separate vapor transfer port to the underground tank. This two-point vapor recovery system requires both a vapor and a fill port. A single-point vapor recovery system uses the drop piping to transport using a special coaxial elbow. Two-point systems are preferable due to faster unloading.

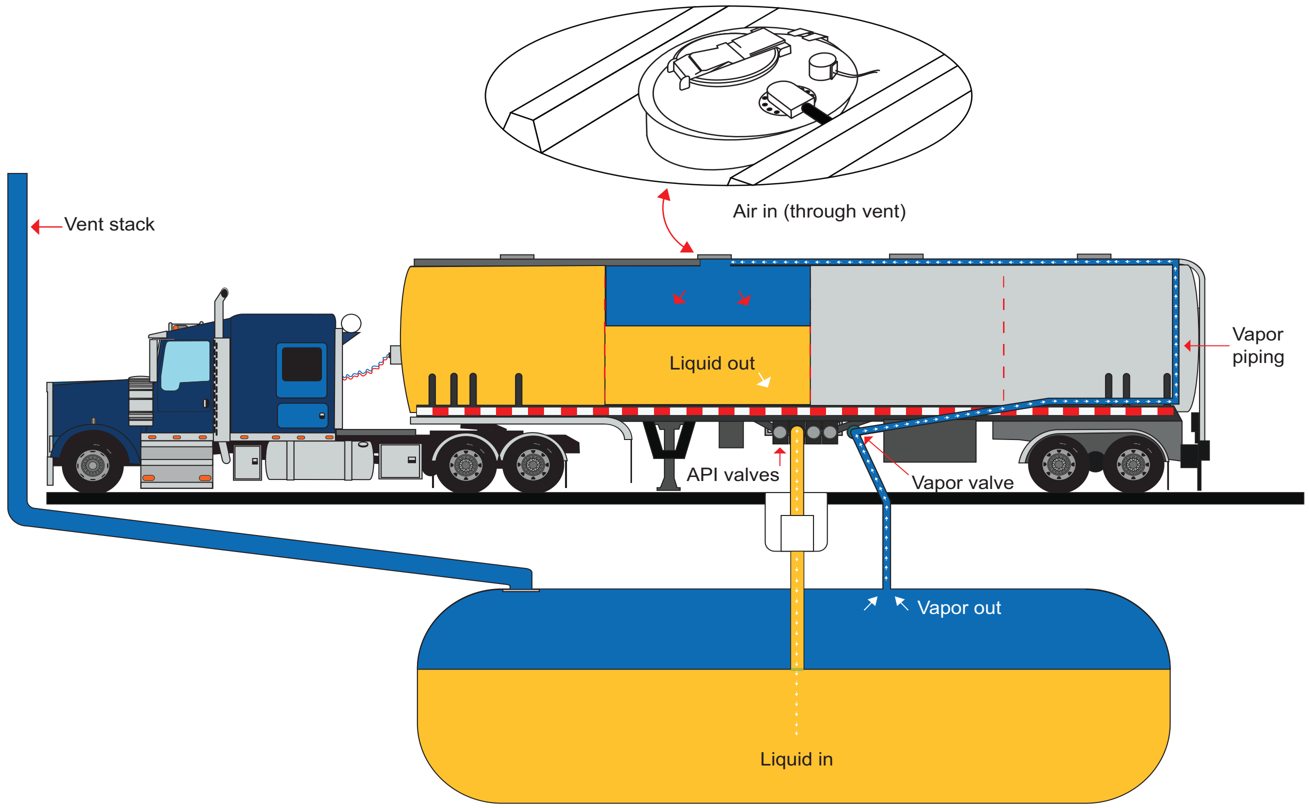
Stage 2 vapor recovery involves the prevention of automobile tank vapors from escaping using special nozzles and additional modification to service stations. This whitepaper will deal only with stage 1 vapor recovery. However, an illustration of stage 2 vapor recovery is provided (see illustration J on page 12).

Illustration H: Stage 1: Vapor Recovery at the Terminal Service Station

Petroleum tank truck bottom-loading at terminal (with vapor recovery)



Petroleum Tank Truck Dropping Fuel at Service Station (two-point vapor recovery system)



Petroleum Tank Truck Dropping Fuel at Service Station (single-point vapor recovery system)

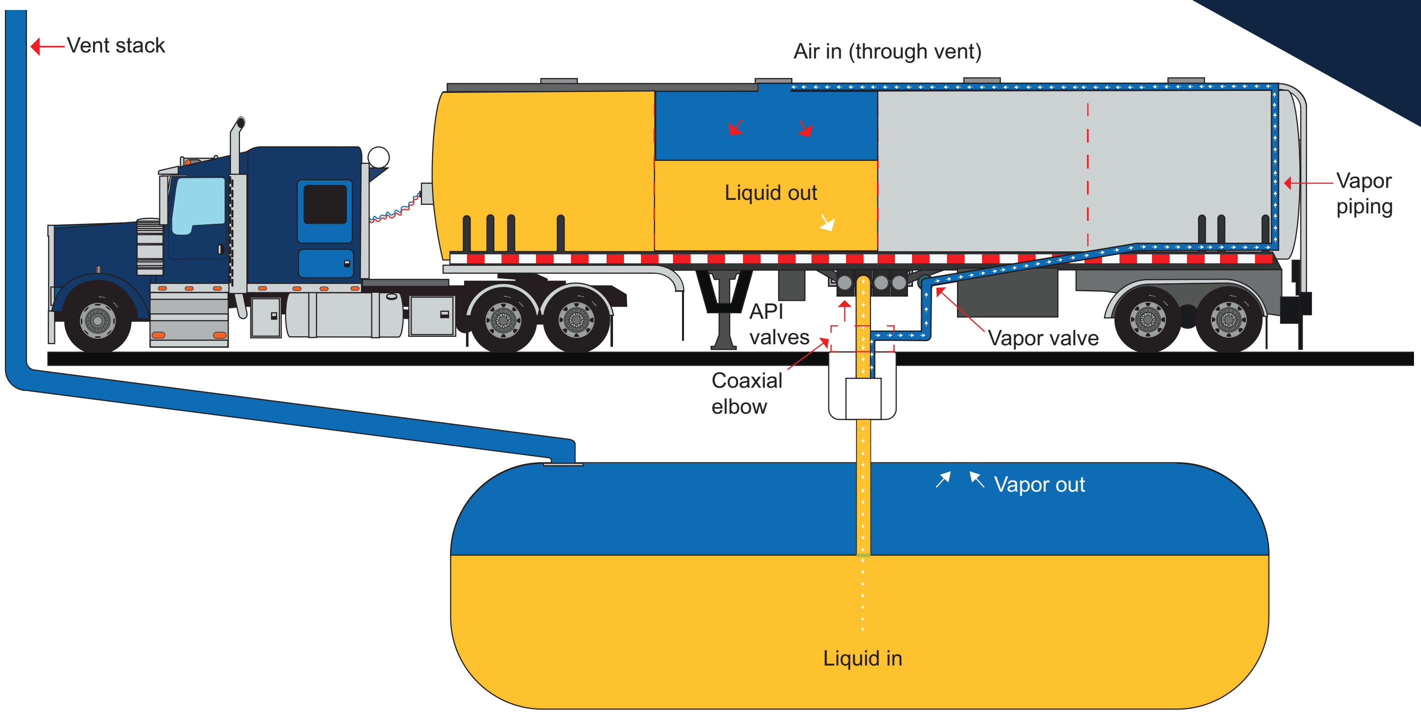


Illustration I: Tank Truck with Hook-up at Service Station with Vapor Recovery

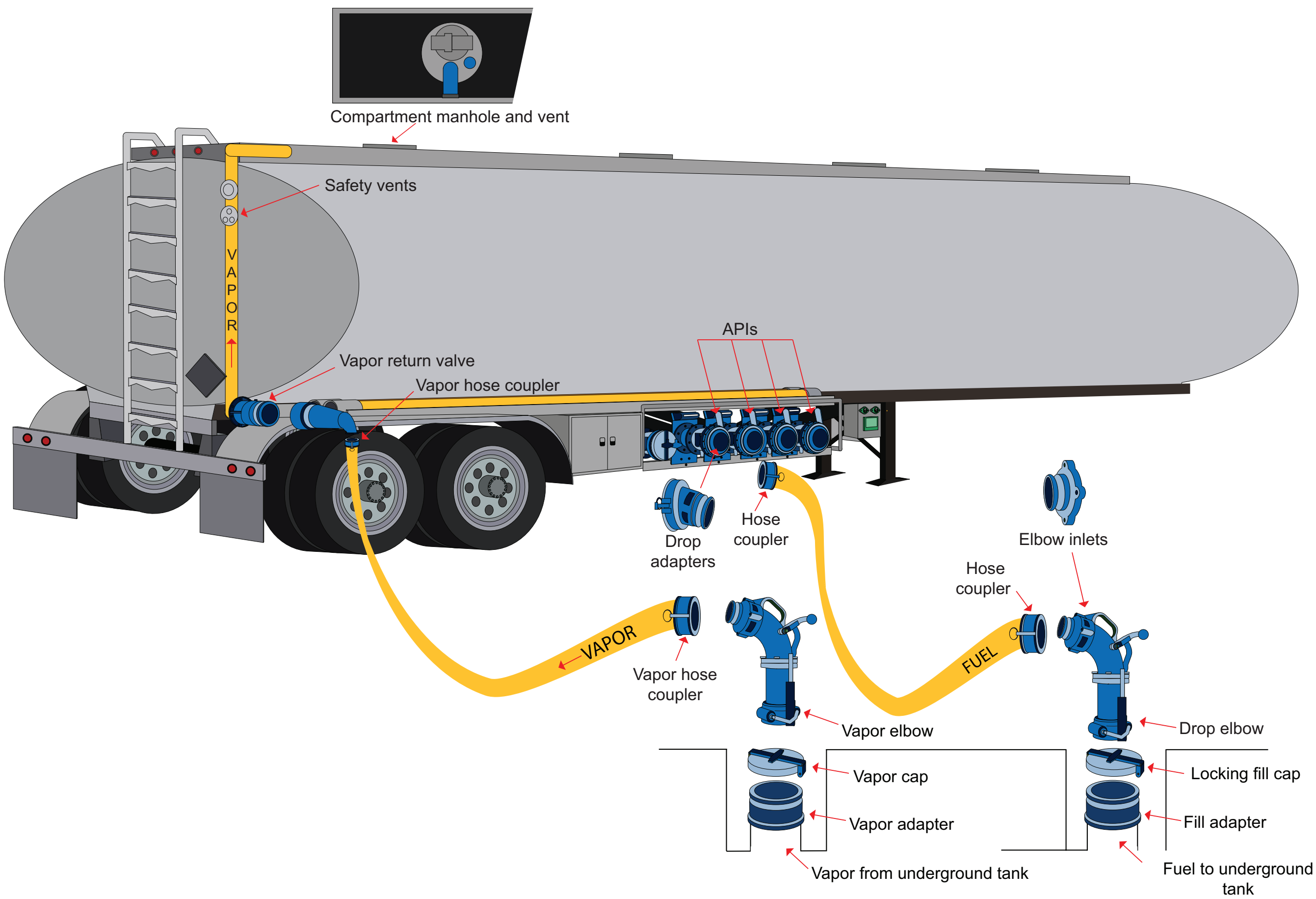
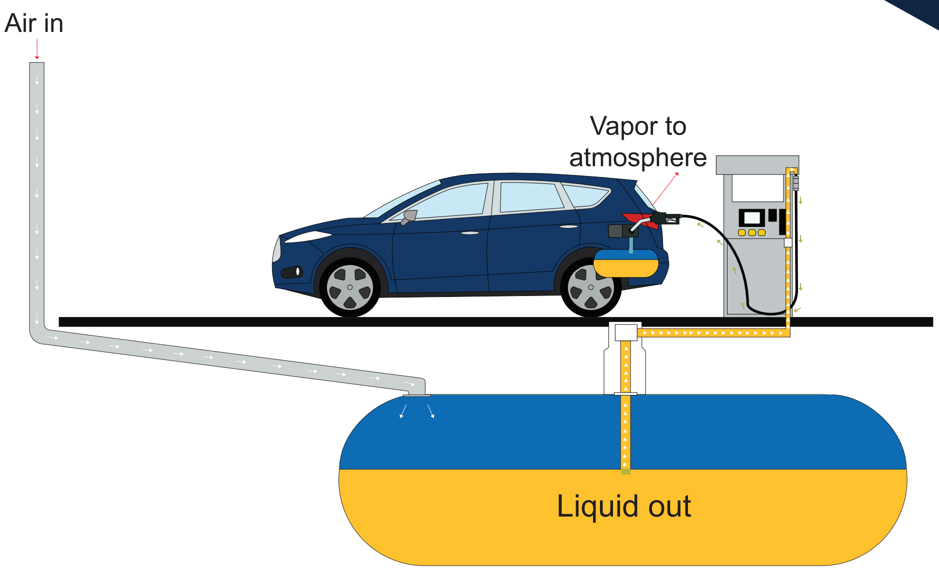
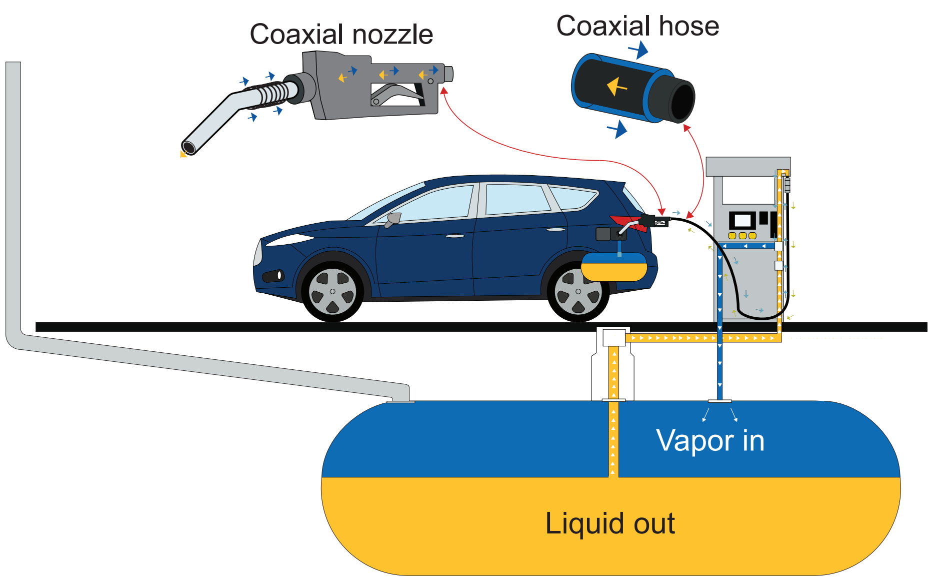


Illustration J: Stage Two Vapor Recovery



Without stage two: vapors from auto gasoline tank escape to atmosphere when filling at service station.



With stage two: vapors from auto gasoline tank are collected and returned to underground service.

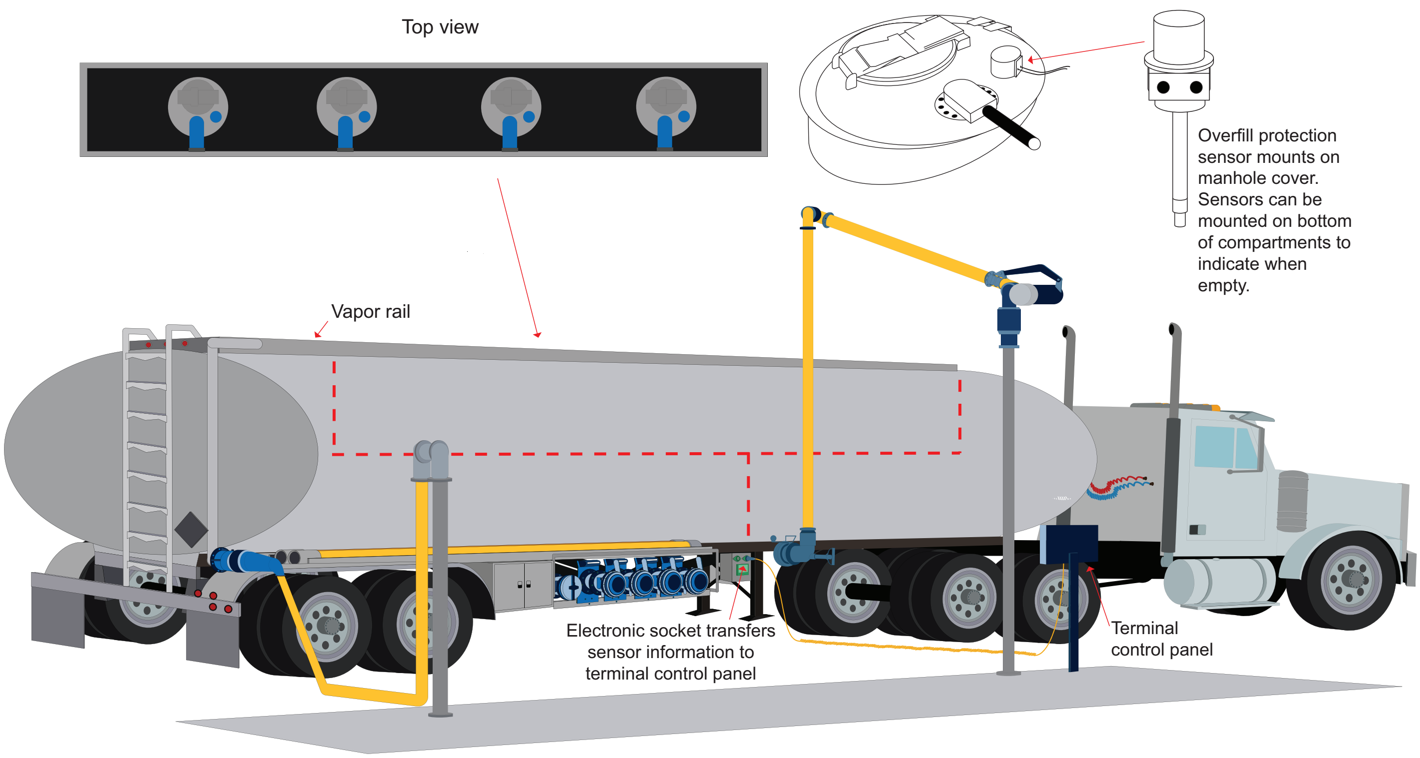
OVERFILL PROTECTION

Overfill protection has evolved and become more complex, especially with the adoption of sealed transportation systems that do not allow for visual inspection. Bottom-loading and vapor recovery applications are two examples of sealed systems. As automation increases, so too does the danger of overfilling compartments. This can occur when:

- Incorrect information is given to the pump/metering device at the terminal
- There is a failure of the pump/metering device
- Operators attempt to fill an already full compartment
- Tankers return to the terminal with an undelivered partial load

Early mechanical overfill protection systems, such as floating ball cut-off devices and pneumatic Venturi cut-offs, could not easily be checked and were found inconsistent. Today the only reliable and verifiable performing equipment is electronic monitoring systems. These electronic overfill protection systems work in conjunction with terminal equipment to serve as a secondary shut-off mechanism should the terminal loading equipment fail, or when operator error results in an overfill situation.

Illustration K: Tank Truck with Overfill Protection



Electronic overfill systems typically consist of:

- An electronic sensor located at the interior top of each compartment, usually mounted on manhole covers. The sensor signals if it is wet or dry.
- Bottom sensors, which are sometimes installed to check if the compartment is empty.
- An electronic socket on the bottom exterior of the tanker, which is electronically connected to each sensor. The socket includes physical grounding.
- The Dixon FT7000 rack overfill monitor at the terminal loading rack, which is connected by cable to the tanker socket. The monitor continuously checks each sensor to permit the pumping of petroleum. If a sensor becomes wet, the signal is interrupted and immediately shuts down the rack pumping equipment. A shut-off signal can result from the top sensor changing from a dry to a wet signal signifying the compartment is overfilled. At the terminal, if the bottom sensor is wet (signifying a compartment is not empty), loading will be prevented.

VAPOR PROCESSING AT THE TERMINAL

Petroleum vapors collected at the terminal are typically processed through large reactors filled with activated carbon. The activated carbon acts as a filter, trapping the hydrocarbon molecules. When saturated, the molecules are drawn off the carbon by vacuum, and the resulting product is condensed and reintroduced to the gasoline manufacturing process. There are typically two reactors. As one reactor is collecting the hydrocarbons, the other is under vacuum, discharging the vapor by product.

In some locations, gasoline vapors are collected but not processed. They are simply burned (flared) into the atmosphere.

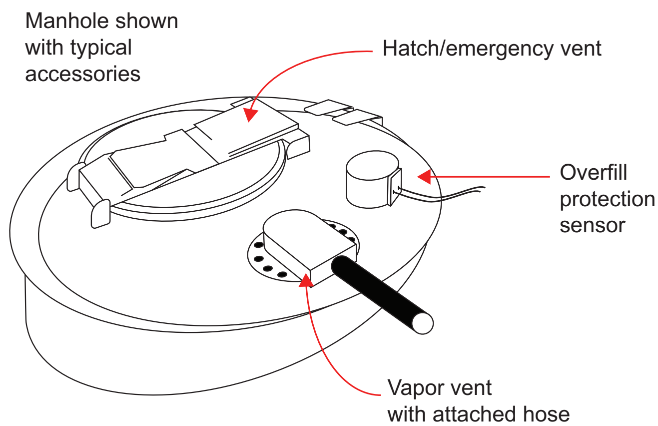
BOTTOM-LOADING AND VAPOR RECOVERY EQUIPMENT

Manholes and Manhole Accessories
Manholes provide personnel entry to the petroleum tanker compartment. Manholes typically come in diameters of 16” and 20”. They consist of a ring welded to the top of the compartment onto which the manhole cover is mounted. The cover is typically manufactured with mounting locations for ancillary items, such as an inspection hatch, vapor vents, and overfill protection sensors.

There are several accessories that can be mounted on manholes. The most important is the emergency vent, which is designed as a surge suppression relief valve. It will open in case of an emergency, such as the overfilling of the compartment (preventing excessive pressure buildup), or for pressure relief in case of a fire, which can cause tanker pressure buildup. These vents open when pressure exceeds approximately 3.6 PSI. This 10” vent is also a hatch, which can be manually opened for filling the compartment or for inspections. The emergency surge vent is a mandatory requirement for North American (DOT 406) petroleum tank trucks and has a very high venting capacity.

Another required accessory is a “normal” or PV vent, which is usually thread mounted and protrudes to the underside of the cover. This small, limited capacity vent compensates for ambient-temperature-generated pressure or vacuum buildups. This in-and-out breathing vent moderates compartment conditions close to exterior atmospheric pressures.

Other accessories mounted on manhole covers can include a vapor vent (described below) and overfill protection sensor.



VAPOR VENTS

Vapor vents are required to allow air/vapor into or out of the compartment during loading and unloading. They prevent a vacuum or pressure buildup in the compartment and allow for smooth and rapid filling or unloading.

Today, vapor vents are generally mounted onto the manhole and are pneumatically operated. Pneumatic manhole mounted vents are popular because they can be controlled by air valves and are normally operated with the emergency valve by a pneumatic control box on the tanker. The operator simply pulls the control knob for the required compartment. Pneumatic vents can also have a built-in sequencing feature to verify all vents are open prior to loading.

Tank trucks equipped for vapor recovery will have the vapor vent adapter connected to the vapor piping systems using a short length of hose. Some mechanical vents may need special hoods (metal or rubber) with spouts to connect to the vapor plumbing.

Pneumatic vapor vents

Sequential vapor vent-threaded
VR6030SQ

Sequential vapor vent-TTMA flange
VR6035SQ

EMERGENCY VALVES

The emergency valve (sometimes called a foot valve) controls the entry and exit of petroleum from the tanker compartment. Located at the bottom of each compartment, the emergency valve is connected to the API valve by piping and can be either mechanically or pneumatically operated. The emergency valve is designed to minimize turbulence and spray of petroleum and therefore reduce the possibility of generating static electricity.

The emergency valve remains shut and prevents compartment discharge should a vehicular collision occur. For example, if an automobile

Dixon as a Solution

Did you know that Dixon Bayco offers solutions to your bottom-loading and vapor recovery challenges?

API drop adapters:

- Materials:
  body - aluminum,
  seals - Baylast, FKM, Buna-N
- Sizes: 3" and 4"
- Options include models with built-in sight glass

Vapor recovery elbows:

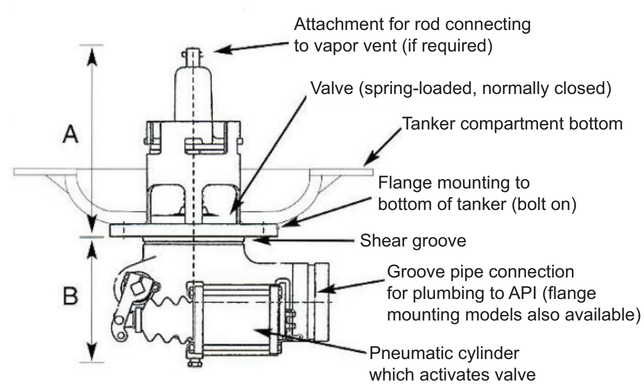
- Materials:
  body - aluminum,
  seals - Baylast, Buna
- Options include handle styles such as D, push-on, ball lever, and elbows with or without a poppet

Vapor recovery couplers:

- Materials:
  body - 356T6 AL,
  seal - Buna-N
- Size: 4" x 3"
- Options include a probe connected to a spring-loaded poppet or couplers only with a probe

collides with the tank truck undercarriage, the emergency valve will automatically close or remain shut, preventing the product in the compartment from escaping. A shear groove on the exterior of the emergency valve is designed to break away along with the piping leading to the API valve. However, the main poppet (valve) is designed to remain closed and intact on the inside of the compartment. The danger of product discharge is therefore limited to the short length of plumbing between the shear section and the API. The breakaway design prevents the compartment contents from being discharged and causing a more dangerous situation.

Typical Pneumatic Emergency Valve



A. In an emergency, this section with closed valve inside the compartment remains with tanker.

B. In an emergency, this section (outside the compartment) is designed to break away at the shear groove, along with the piping to the API valve.

The trend is to pneumatically operate emergency valves. However, mechanically activated emergency valves (controlled by cable operated levers) are still in use. Mechanical emergency valves often control vapor vents via a metal rod connected to both. The emergency valve and vapor vent operate simultaneously. Both items are opened during the loading and unloading process. Both remain closed at all other times.

AIR INTERLOCK VALVES

Air interlock valves are simple, plunger-activated air valves that are linked to the truck airline system and used to direct pressurized air to activate other pneumatic devices on the tanker. There are many variations of air-activated systems used by transporters. Emergency valves, vapor vents, and trailer air brakes are commonly controlled devices. Air interlocks are often mounted on API valves, vapor valves and safety bars and can be activated by coupling of hose, or terminal dry breaks, or by operating the safety bar. Air interlocks allow for improved safety, reduced operator error and improved automation when loading and unloading petroleum. Several air interlocks are often found on petroleum trailers.

Standard air interlock model
5000AIHD

Air interlock with valve paddle plunger
5000AIVHD

API VALVES

There are two basic styles of API valves: those that can be opened with a handle and those with no handle. By far the most popular product is the handle model; it allows for both loading and unloading of the tanker through this common valve.

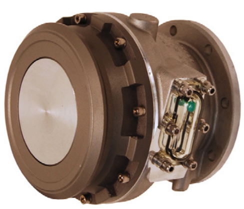
Both API models are spring-loaded, 4” poppet valves, which at the terminal mate with a specially designed API dry break coupling. The nose/coupler geometry of the API valve is made to a specific standard (API recommended practice API RP1004:2003). The two items, the API valve (on the tank truck) and the API coupler (at the terminal) are designed for the fast, easy, and drip-free connection and transfer of gasoline from the terminal to the road tank truck.

At the service station, a drop hose is connected to the handle model API valve. The other hose end is connected to the drop elbow and the underground tank pipe. Gasoline is gravity transferred from the tank truck to the underground tank when the API valve is opened by use of its handle (see illustration F on page 8).

Load-only APIs (no handle) are not utilized during service station drops. Flow is controlled by a separate “Y” valve or “Y” plumbing with a faucet or butterfly valve (see illustration G on page 9). Older style manifold systems can also employ load-only API valves.

GRAVITY DROP ADAPTERS

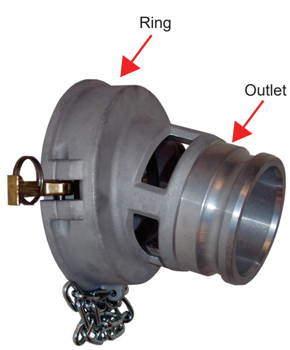
Drop adapters are part of the service station unloading system when using API valves that are opened manually. Gravity drop adapters are simple couplers designed to attach and lock onto the API nose geometry on one end and allow attachment to a standard cam and groove hose couplings at the other end. They permit the drop hose, which uses standard cam and groove hose couplers, to link the API valve to the drop elbow and the underground tank.



API load-only valve
5204L

API load/unload valve
5204NG

API dust cap
5205



Sight glass models require assembly of ring to outlet.
4540SG

Drop adapters are sometimes stored in the tool compartment of the tank truck until required during unloading at the service station. In some cases, they are left on the API and removed only when loading at the terminal.

Gravity drop adapters typically come in two sizes for use with either 3” or 4” hose.

DROP HOSE

The drop hose is used to transport gasoline between the tank truck and the underground tank during unloading at the service station. Standard cam and groove aluminum hose couplings are used on each end. Using 4” diameter hose provides fast unloading; however, 3” diameter hose is common because of reduced weight and cost.

DROP ELBOWS

Drop elbows are typically carried on the tanker and connect the underground tank collar to the drop hose. Elbows are used extensively throughout North America, Mexico, and parts of South America. They are not common in Europe and Asia. Elbows protect drop hose from damage due to kinking. They also make hose connection to the underground tank more convenient. It should be noted that drop elbows are designed for use with a special underground tank collar.

By far the most common elbows are for 4” top seal collars. Most service stations have standardized on 4” fill piping.

UNDERGROUND TANK COLLARS

The style and size of tank coupling will vary depending upon the country and whether vapor recovery is being used.

In North America, stations are usually equipped to use 4” drop elbows, which attach to 4” top seal couplings (a few older stations have 3” piping). In some locations 4” side seal elbows and couplings are employed. Elsewhere in the world standard cam and groove hose fittings are common in addition to special regional designs.

INLETS 3” and 4”

6000-16

6000-14

TOP SEAL ELBOWS

6500A

6200A

SIDE SEAL ELBOWS

6000ASA

Service stations equipped with vapor recovery have a second outlet on the underground tank to allow vapor to escape and be transferred to the tanker during the unloading cycle. These outlets use a standard 4” quick coupler adapter but with a built-in, spring-loaded poppet (valve).

Where vapor elbows are employed, the elbow contains a bottom probe, which opens the valve when coupled to the collar. The adapter profiles for 4” top seal fill and vapor couplings are different to prevent drop elbows from attaching onto vapor collars and vapor elbows from attaching to fill collars.

VAPOR ELBOWS

Vapor elbows are similar in design to drop elbows and function to make the vapor hose connection convenient for operators and to the hose from splitting due to kinks. When mounting, a probe on the bottom end automatically opens the poppet on the vapor collar, allowing vapors from the underground tank to escape. The vapor hose connects to the 3” adapter outlet on the elbow.

Vapor elbows are typically designed with 3” diameter bodies and with a 3” male adapter outlet. However, note that vapor service station piping and vapor collars are 4”.

4” top seal
collar/adapter
BZ4051

4” vapor
collar/adapter
VR4086

4” side seal
tank adapter
BSS4051

For stations that do not have a separate vapor outlet, a special co-axial elbow can be used. This elbow (6400X, bottom photo) allows for both the drop of gasoline and the escape of fumes through a standard 4” top seal drop collar. A tube-within-a-tube design allows fuel to be dropped through the inside tube, while vapors escape around the outside. This is called a “single-point delivery system”, compared to the two-point system, which has separate dedicated vapor and drop fittings. Two-point systems are preferred due to faster delivery drop-off.

Dual-point vapor recovery elbow
VR6200ANP

Heavy duty dual-point vapor recovery elbow
VR6500

(available with and without poppet)

Single point coaxial drop elbow
6400X
(3” and 4” male and female inlet models available)

VAPOR HOSE AND FITTINGS

The vapor hose is typically 3” diameter (4” common at terminals). For connection to the vapor elbow, the hose can be equipped with a standard 3” shanked quick coupler. However, should the Dixon Bayco VR6200 vapor elbow be employed (with exit poppet) then the VR3000AL (with probe) is required. The probe is needed to open the exit end poppet on this vapor elbow model.

At the tank truck end a special 4” x 3” probed hose coupler is needed. The coupler connects to the vapor valve on the tank truck. The coupler probe is required to open the poppet in the vapor valve.

3” with probe
VRC3000AL

4” x 3” with poppet and probe
VR4030CS-AL

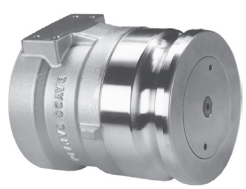
4” x 3” without poppet with probe
VR4030CS-SH

VAPOR VALVES

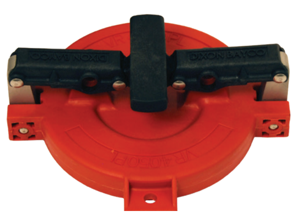
The 4” vapor valve allows entry of displaced gasoline fumes from the underground tank to the 4” vapor piping system on the road tanker. The vapor hose coupler probe automatically depresses (opens) the poppet in the vapor valve when coupled.

Dixon Bayco provides two models: VR4000, high flow design with sight glass and drain plug and VR4100, standard model. The high flow design provides low resistance to vapor flow for fast loading of tank truck compartments at terminals. However, the VR4100 is more popular as a standard in the industry.

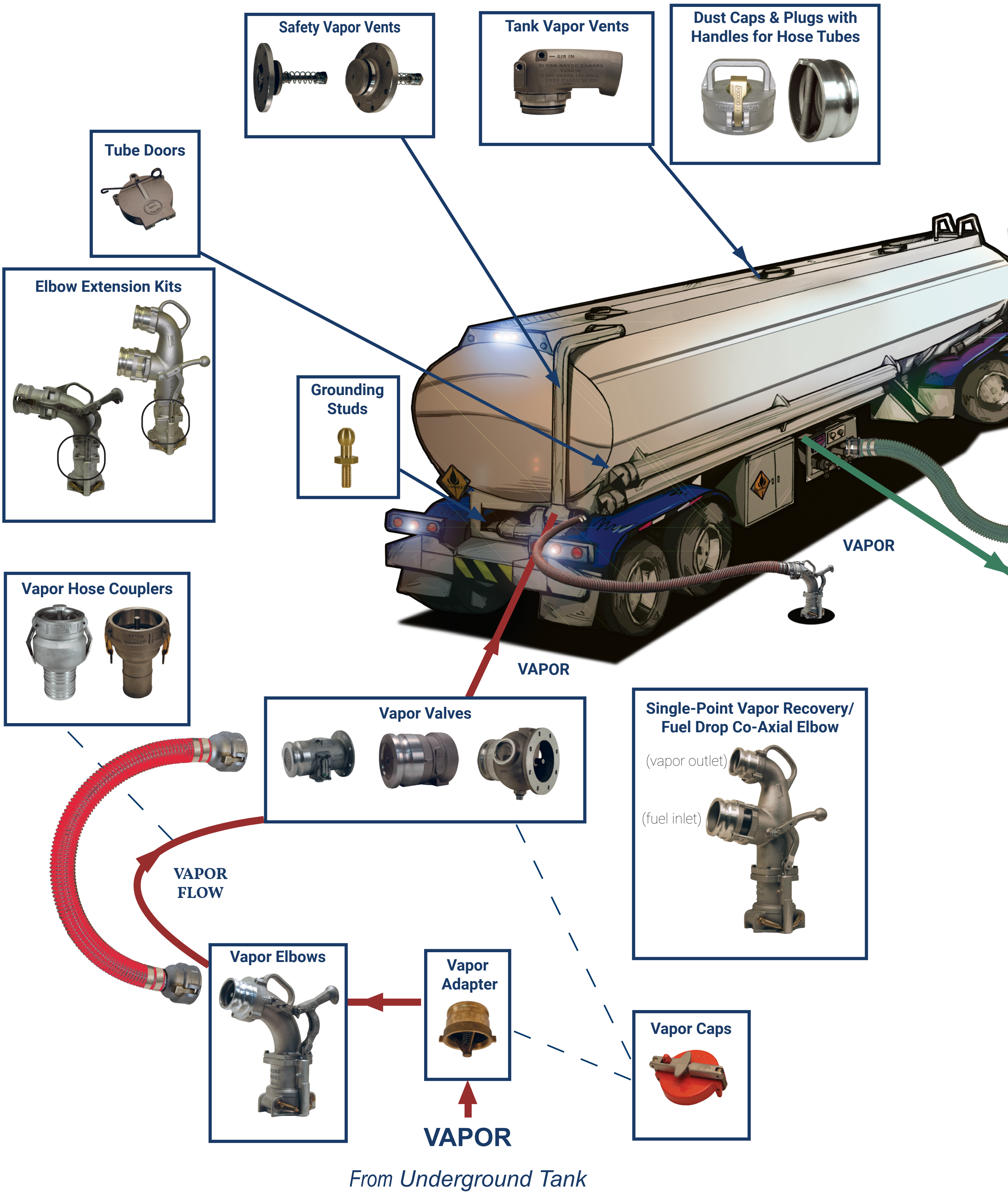
Vapor return valve
TTMA flange
VR4000

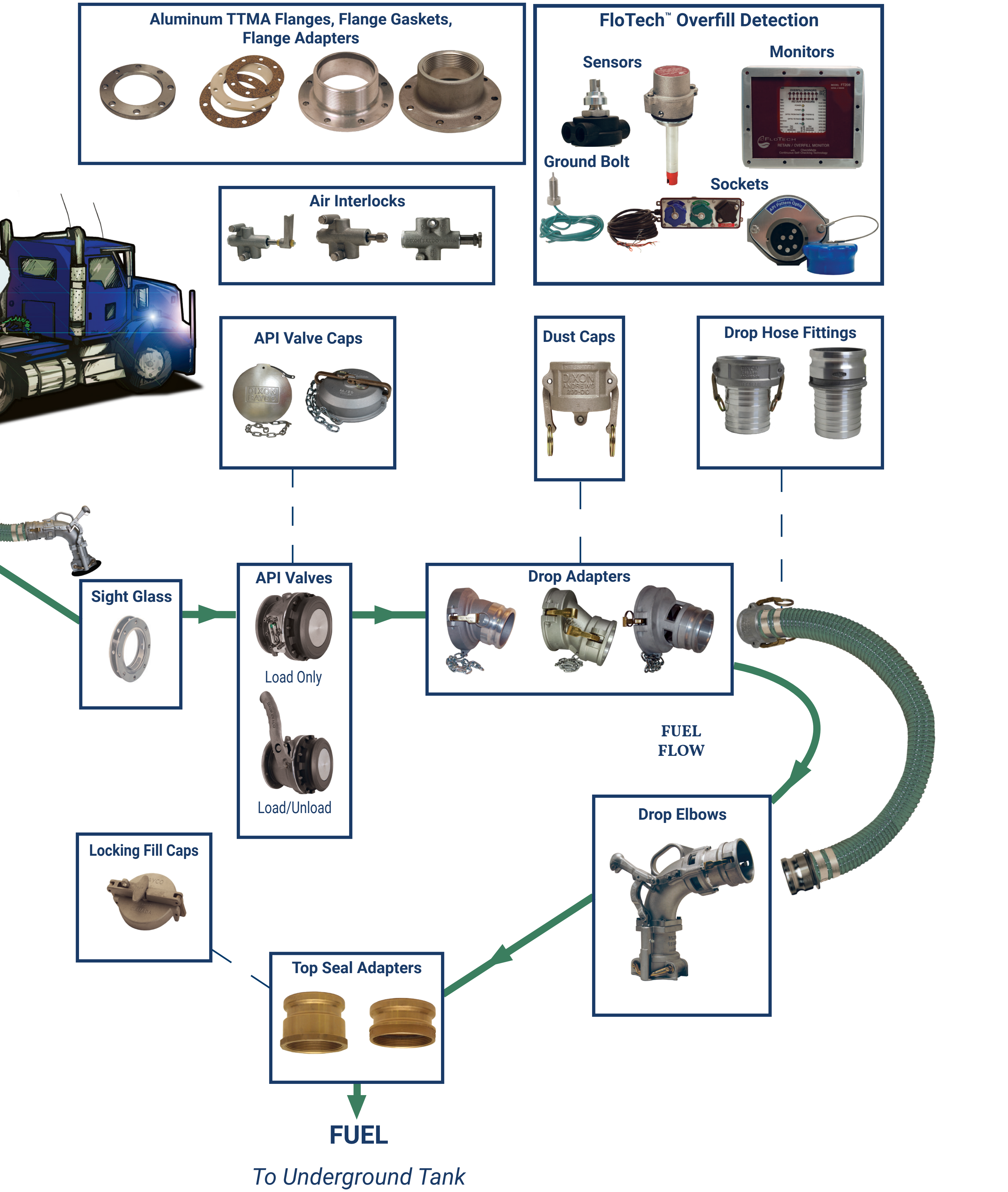


Vapor return valve
female thread
VR4100



Vapor cap
VR4050PL


Safety Vapor Vents
Tank Vapor Vents
Dust Caps & Plugs with Handles for Hose Tubes
Tube Doors
Elbow Extension Kits
Grounding Studs
VAPOR
Vapor Hose Couplers
VAPOR
Vapor Valves
Single-Point Vapor Recovery/ Fuel Drop Co-Axial Elbow
(vapor outlet)
(fuel inlet)
VAPOR FLOW
Vapor Elbows
Vapor Adapter
Vapor Caps
VAPOR
From Underground Tank


Aluminum TTMA Flanges, Flange Gaskets, Flange Adapters
FloTech™ Overfill Detection
Sensors
Monitors
Ground Bolt
Sockets
Air Interlocks
API Valve Caps
Dust Caps
Drop Hose Fittings
Sight Glass
API Valves
Load Only
Load/Unload
Drop Adapters
FUEL
FLOW
Drop Elbows
Locking Fill Caps
Top Seal Adapters
FUEL
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Robert Koeninger has 32 years experience in the petroleum cargo tank industry with a total of 41 years experience in commercial and military electronic packaging and design. Robert holds seven U.S. patents on various liquid level and control designs. He started FloTech Inc, which is part of the Dixon Bayco Division of Dixon Valve and Coupling Company and a leading manufacturer of liquid level sensing and control systems for the petroleum bottom-loading industry. Robert is a graduate of Cincinnati State in electrical engineering technology.

Founded in 1916, Dixon is a premier U.S.- based worldwide manufacturer and supplier of hose couplings, valves, dry disconnects, swivels, and other fluid transfer and control products. Dixon's products and services support a wide range of industries, including chemical processing, petroleum exploration, refining and transportation, steelmaking, construction, mining, manufacturing, and processing.

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