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Fuel Tanks Imbalance Problem

February
2000

Project teem

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Svetlana Visnepolschi received an MS in electronics from the Leningrad Institute of Precision Mechanics and Optics in 1976. She became a student of Genrich Altshuller, the founder of TRIZ in 1983. Her early contribution to TRIZ includes the creation of the working algorithm for TRIZ Resources (together with B. Zlotin). She later pioneered various projects in the application of TRIZ prediction methods to the development of both industrial systems and business; included with that latter are the Moscow Stock and Commodity Exchange and the election campaign. Ms. Visnepolschi has been teaching TRIZ for more then 15 years; she authored a book and numerous publications. Since 1985, she has been providing development and application of the TRIZ-based Anticipatory Failure Determination (AFD) Methodology. Since 1997 she is the Project Manager for the Ideation International Inc. and the designer of Ideation AFD System software.

Contents

Summary

The following summary contains the results of the investigation for the fuel tanks imbalance phenomena and suggestions for preventing and correcting the imbalance. The work was performed by utilizing the AFD software for formulating the hypothesis and the IWB software for developing suggestions.

In particular, the following work was completed:

- Failure Analysis Questionnaire
- Graphical descriptions (models) of the system (a set of 4 graphic models)
- Revealing all possible resources for the development of fuel tanks imbalance mechanisms (13 different types of resources)
- Graphical descriptions (models) of possible fuel tanks imbalance mechanisms (a set of 5 graphic models)
- Hypotheses developed for possible fuel tanks imbalance mechanisms (7 different hypotheses), including:
  - Fuel level imbalance in winter (temperature is below freezing point)
  - Fuel level imbalance during the summer
  - Circular flow patterns formed by return flow
  - Imbalance of the flow in return tee
  - Gradual accumulation of differences in the temperatures of the tanks (truck equipped with two different tanks)
  - Influence of resonant vibration
  - Integrated effect of the different reasons for failure
- Preliminary verification of formulated hypotheses
- Suggestions for experiments to eliminate fuel tanks imbalance
- Set of suggestions for elimination of fuel tanks imbalance (24 suggestions, 14 with variants of implementation) Most promising solutions may be patented.

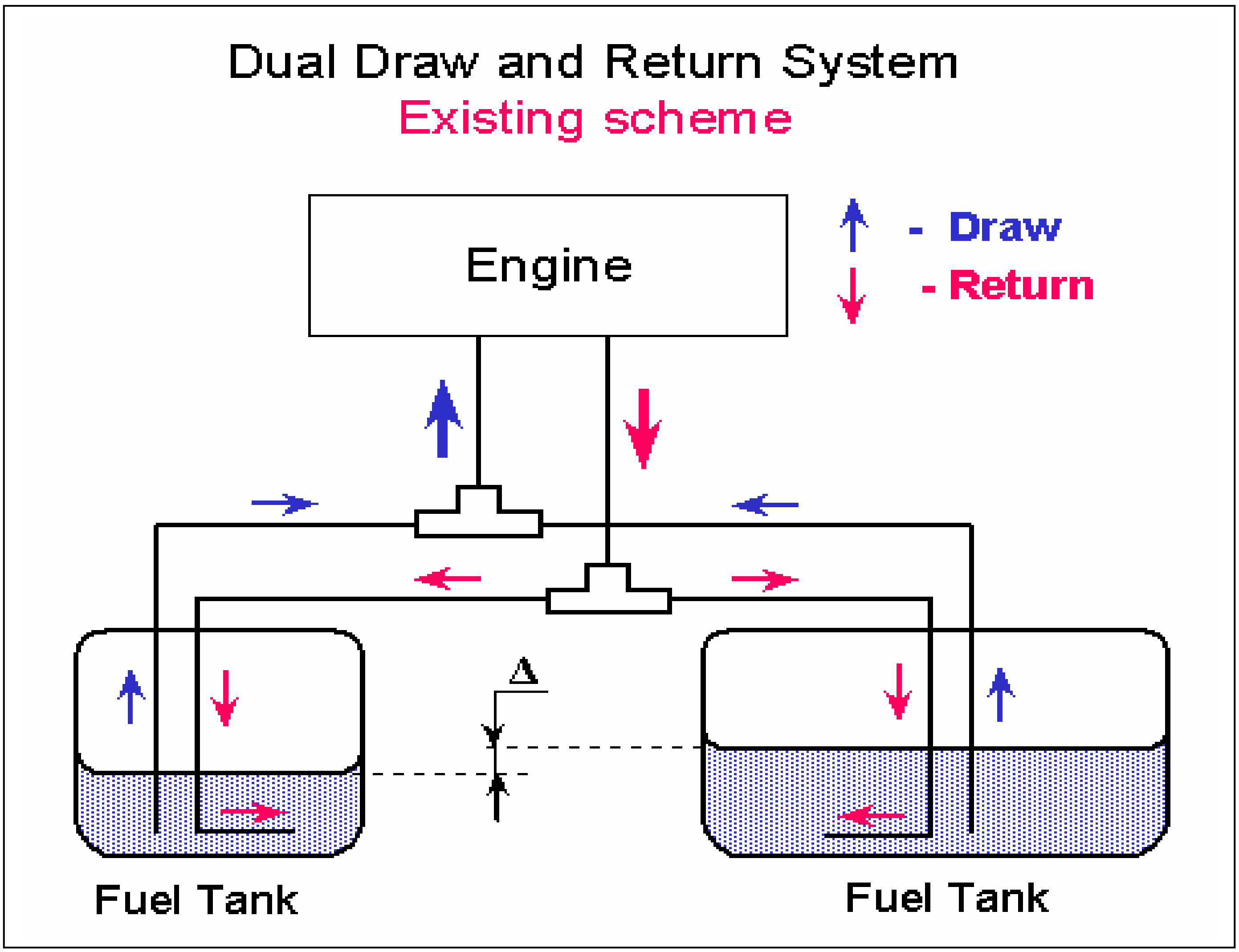
Report consists of 45 pages and includes 3 appendices and 40 figures.

Problem statement:

Trucks with two fuel tanks equipped with a dual draw and dual return system. System is designed for equalization of fuel levels in tanks. Sometimes one of the tanks becomes dry while the other is still full. The system draws air from the dry tank to the engine and the truck stops.

The problem is complicated because:

- the failure time is not predictable
- it is hard to reproduce this phenomenon in laboratory conditions
- there are no established facts for reproduction of the conditions of this phenomenon in literature
- there are many factors, which can affect the imbalance of fuel levels
- not all factors are known
- it is impossible to predict and calculate effects from small irregularities



1. Failure Analysis Questionnaire

1.1. Failure or drawback for which the root-causes are unknown

Unequal fuel quantities in right and left tanks.

1.2. System where the failure occurs

System name

Dual draw and return system

System structure

Tank 1 (no gauge)
Tank 2 (with gauge)

Return
- Return tee
- Return lines
- Fittings
- Pipe

Draw
- Draw tee
- Draw lines
- Fittings
- Pipe
- Vent lines
- Pump

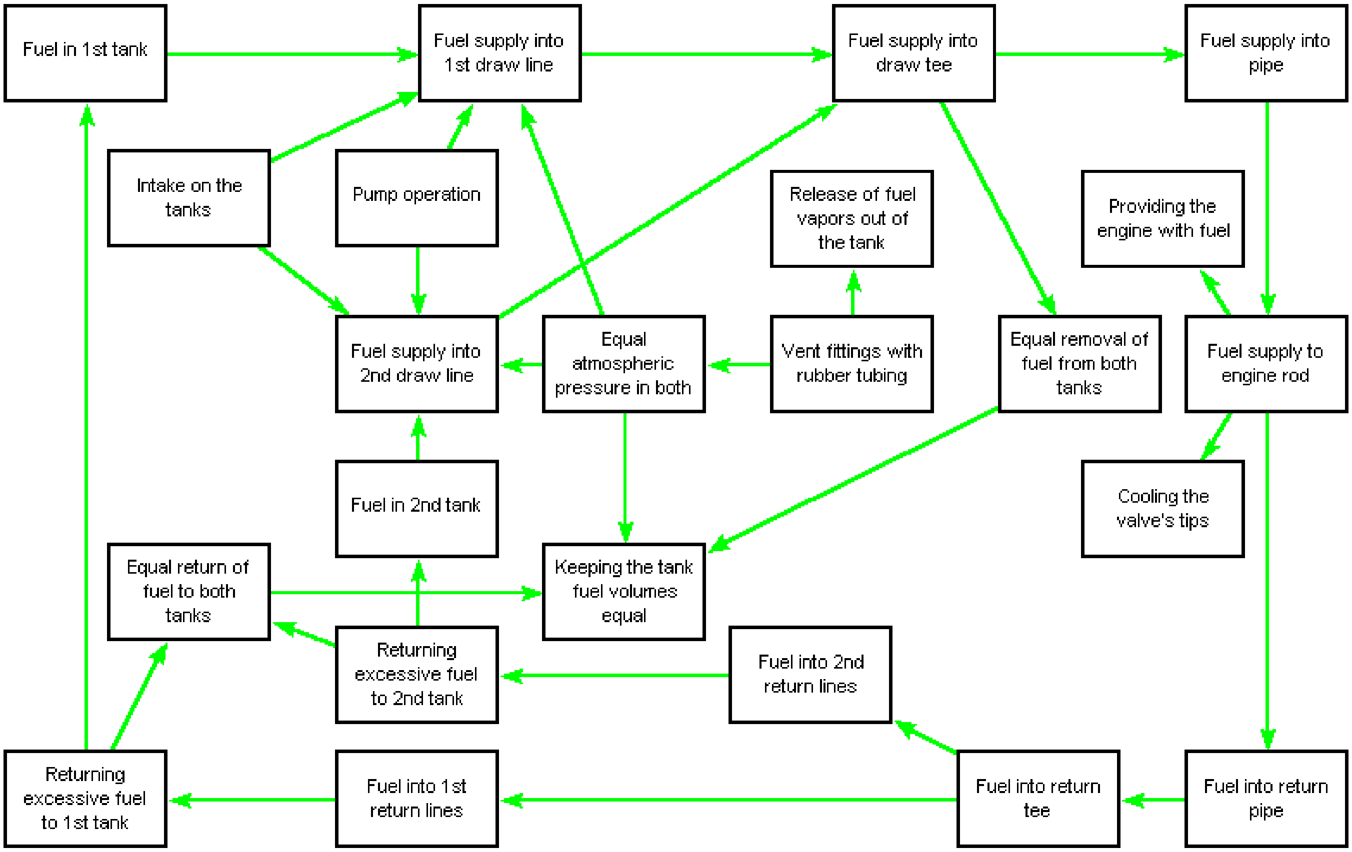
Primary Useful Function

Providing the engine with fuel

Useful functions

1. Keeping the tank fuel volumes equal
2. Cooling the valve's tips
3. Returning excessive fuel back to the tanks
4. Providing information about fuel level in the tanks

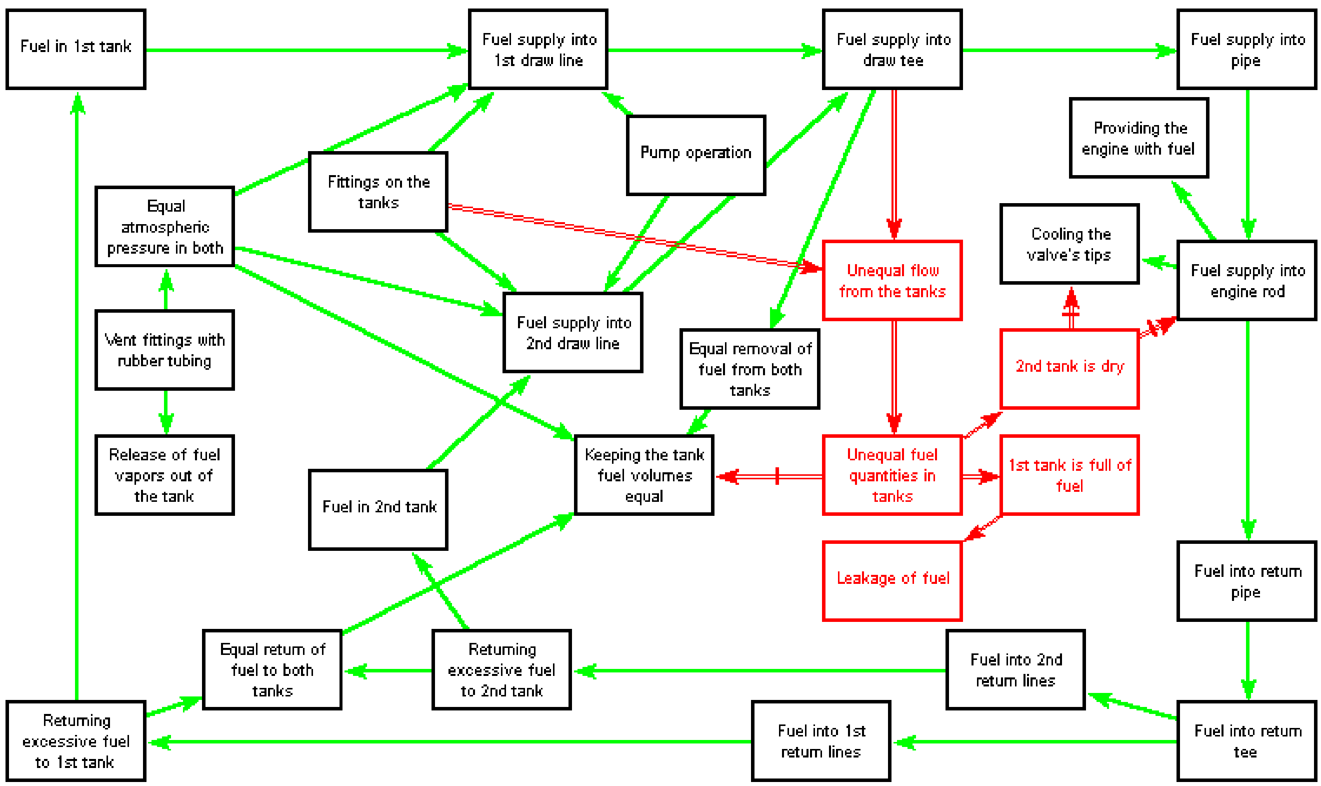
See: 1 Dual draw and return system Problem Graph (Main)



Harmful effects

1. 2nd tank is dry
2. Unequal fuel quantities between tanks
3. Incorrect estimation of remaining fuel
4. 1st tank full of fuel
5. Fuel leakage

See:2 Dual draw and return system Problem Graph (Harmful)



2. Problem Formulation

2.1. Localizing the failure

Last Event

Exact last event is unknown. However, the following events have to be taken into account.

1) Temperature (T) is below freezing
2) Summer fuel (which is lower viscosity and has a different chemistry) is left in tank
3) Established flows inside the tanks
4) Hot conditions
5) Parking on inclines

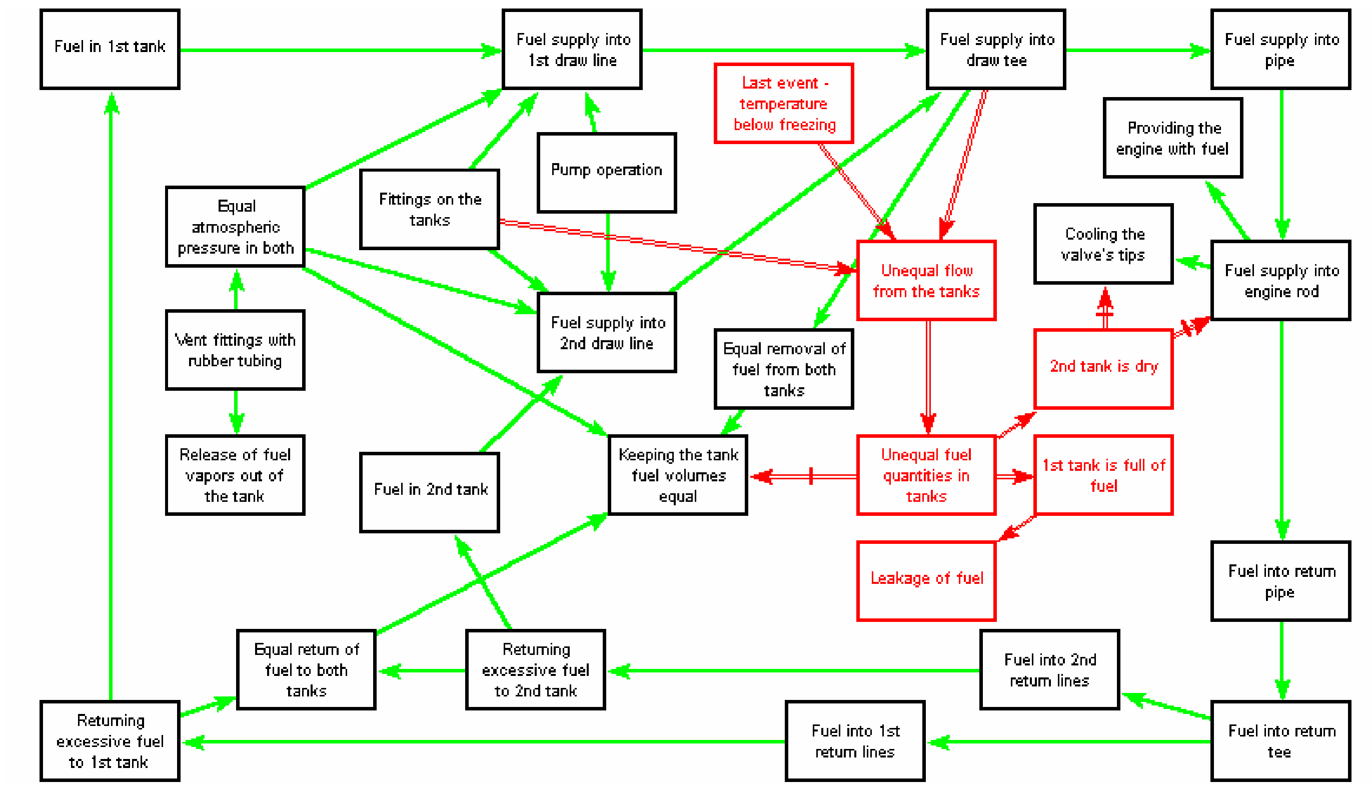
The second iteration of the Failure Analysis revealed that the most important event after which the failure happened was implementation of the Dual Draw and Return System.

Conditions that initiate or accompany the failure

Possible conditions:
1) Difference in quantities of fuel in tanks
2) Low temperature
3) Different temperature (T) of the tanks

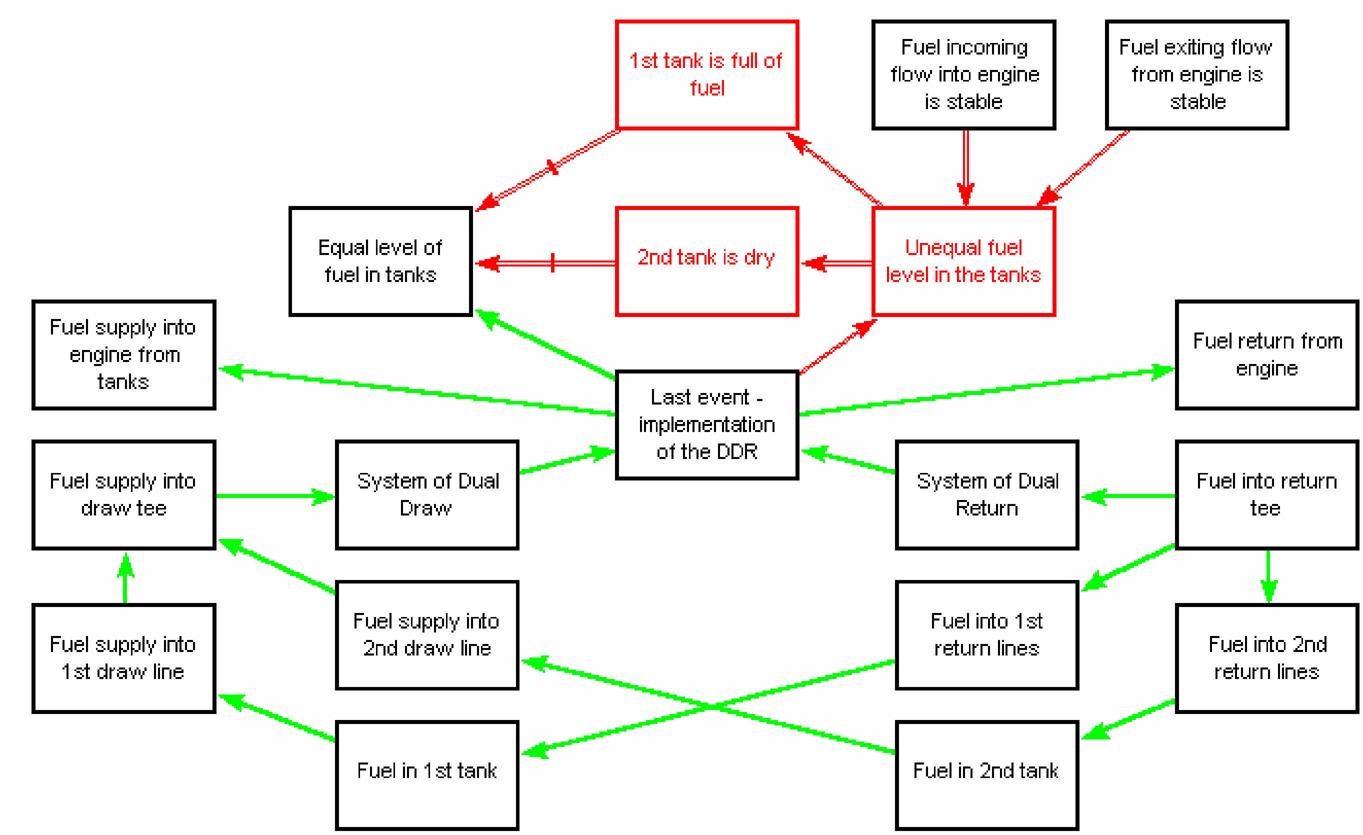
4) Starting and stopping
5) Dynamic load on the curves
6) Continuous heating of one tank by sun
7) Continuous cooling of the one tank (by wind, rain, snow, etc.)
8) Highway driving conditions

See: 3 Dual draw and return system Problem Graph (Localized, example: temperature below freezing)



The second iteration of the Failure Analysis selected the following conditions:
1. Highway driving conditions
   - Fuel incoming flow into engine is stable
   - Fuel exiting flow from engine is stable
2. Extended parking with engine running:
   - Fuel incoming flow into engine is stable
   - Fuel exiting flow from engine is stable

See: 3a Dual draw and return system Problem Graph (Localized, Implementation of the Dual Draw and Return System)



2.2. Formulating the Inverted Problem

Example: Last event - temperature below freezing

1. Find a way to provide [the] (Unequal fuel quantities in tanks) with help of [the] (Last event - T below freezing), (Fittings on the tanks), and (Fuel supply into draw tee), and any other function, which happens before the Last Event.

New formulation of the Inverted Problem (after refinement of the step Localizing the failure)

2. Find a way to provide [the] (Unequal fuel level in the tanks) with help of [the] (Last event - implementation of the DDR System), (Fuel incoming flow into engine is stable) and (Fuel exiting flow from engine is stable), and any other function, which happens before the Last Event.

NOTE: DDR is an abbreviation for Dual Draw/Return

3. Providing Failure Hypotheses

3.1. Amplifying the Inverted Problem

1. Find a way to provide [the] (Constant unequal fuel quantities in tanks) with help of [the] (Last event - T below freezing), (Fittings on the tanks), and (Fuel supply into draw tee), and any other function, which happens before the Last Event.

New formulation of the Amplified Problem:

2. Find a way to provide [the] (Constant unequal fuel level in the tanks) with help of [the] (Last event - implementation of the DDR System), (Fuel incoming flow into engine is stable) and (Fuel exiting flow from engine is stable), and any other function, which happens before the Last Event.

So, after some editing of the automatic formulation the task can be stated as follows:
The Dual Draw and Return System should itself provide constant unequal fuel level in the tanks on conditions of stability of fuel flow to and from the engine.

3.2. Generating Failure Hypotheses

How to produce unequal level in tanks?
To produce unequal level in tanks the following must exist:
1. Return to one tank more than to another tank
2. Draw from the tank less than from another
3. Both variants could be applied together.

Resources for the creation of different levels in the tanks:

- Initial level of the fuel in tanks and its change during driving, stopping, and refueling.
- Irregularities in the fuel system.
- Temperature changes inside and outside the tanks.
- Weather conditions - irregularities of heating by the sun, cooling from the wind and weather conditions.
- Different size, location and configuration of the tanks.
- Position of the tanks during driving, stops and parking
- Different volumes of draw and return of the fuel (because of the difference in volumes of the tanks)
- Vibration of the tanks - difference in size, mounting system, volume.
- Dynamic irregularities of the flows:
  - Different speed of the flows
  - Different pressure of the flows
  - Turbulence and laminar conditions of the flows
  - Change of the flow speed in the system, linked with changes in fuel consumption

Considering Amplified Formulation 2 we can say that to provide constant unequal fuel level in the tanks the Dual Draw and Return System should itself provide effective fuel delivery from small tank into large tank.

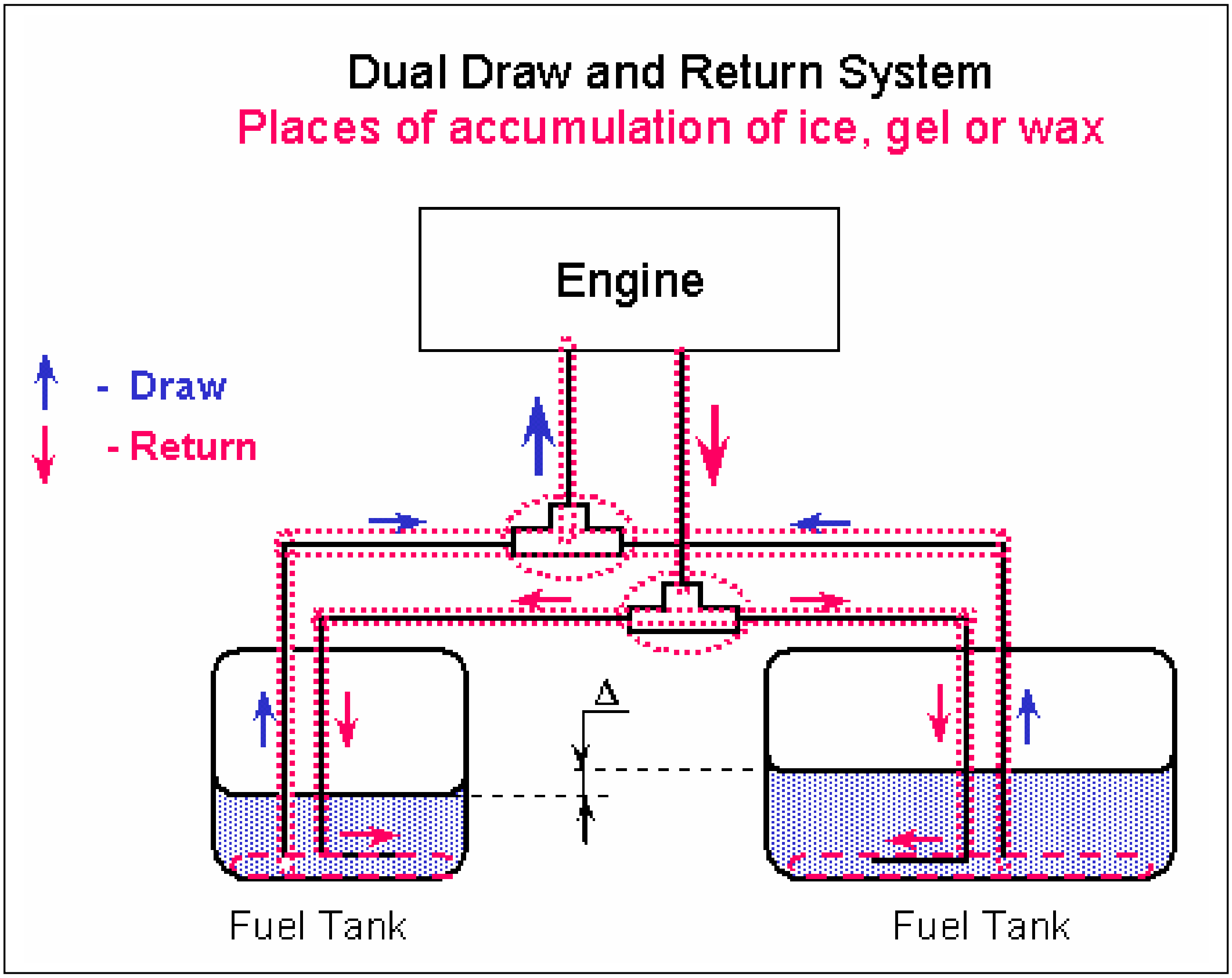
As fuel gauge indicates only fuel level in the large (right) tank, the driver checks the large tank only. When the level in the large tank is low, the driver can see it and can add fuel to both tanks. Therefore the large tank can be empty only on special occasion (when driver doesn't pay attention to the gauge during extended driving, engine is idling for an extended period during parking)

But the driver doesn't know the level in small tank until this tank is empty and engine stops. So it can happen any time.

Questions:
1. Were there any complaints about fuel gauge and sending unit failures?
2. Did anybody complain about different level in tanks at gas stations?

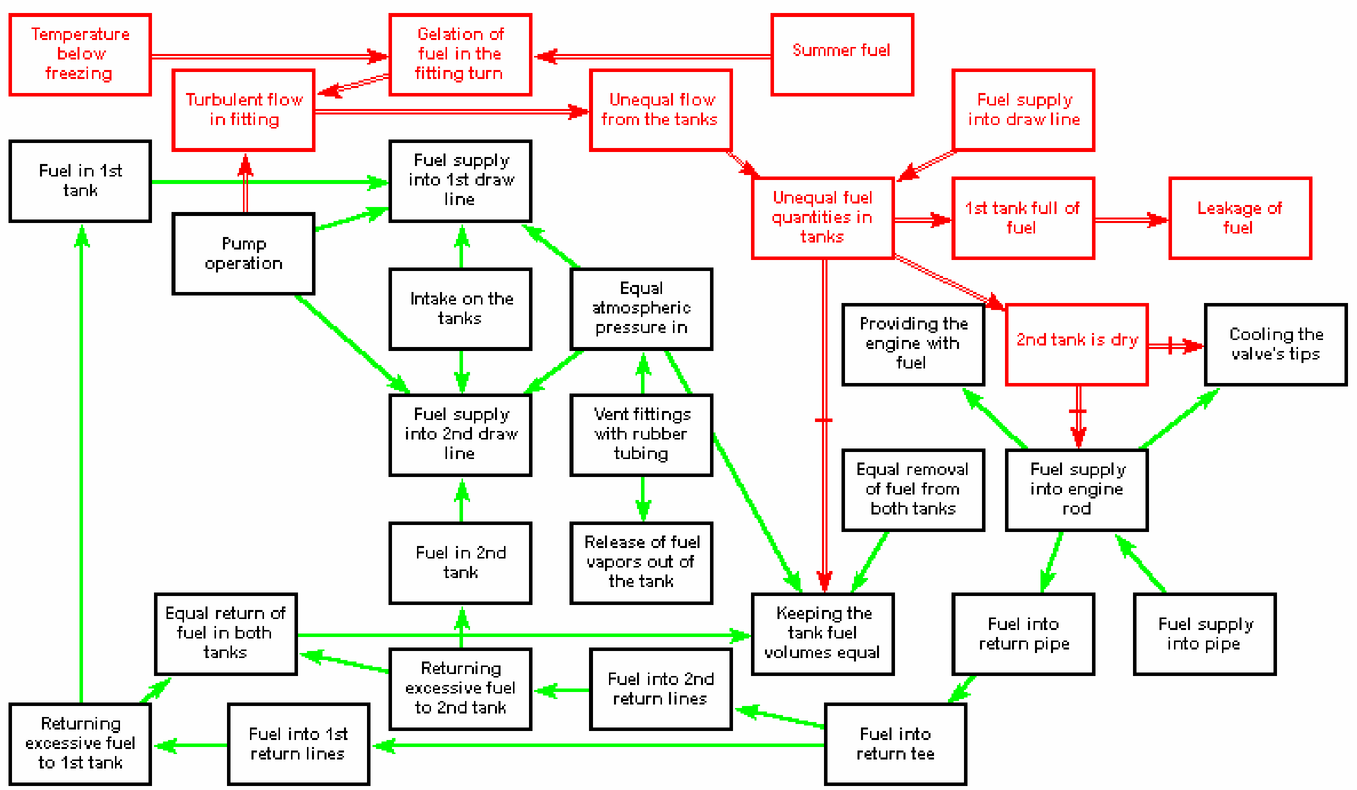
Hypotheses:

1. Fuel level imbalance in winter (temperature is below freezing point).
In the case of low temperature there are number of events, which can initiate imbalances in the fuel system:
a) Freezing of water (or condensation and freezing of water vapor)
b) Thickening (gelation) of fuel
c) Waxing of fuel



Accumulation of ice, gel or wax layers can take place in the following parts of the system:
- fittings on the tanks
- draw tee
- draw pipe
- vent fittings with rubber tubing

Paraffin wax, ice and other materials may crystallize and form solid layers on the internal surface of the fuel lines. These layers can clog or reduce the cross section of the fuel lines. Accelerated accumulation of the solid layers will first take place on the non-uniform surfaces: fittings, tees, and pinch points. Complete blocking of the flow is the extreme case, but reduction of the effective cross-section of draw line from one side will have a crucial effect on the system: i.e., less amount of fuel will be drawn from one of the tanks. The fuel draw system will become imbalanced and the difference in levels can be accumulative during continuous driving. The worst case is second tank can run dry.

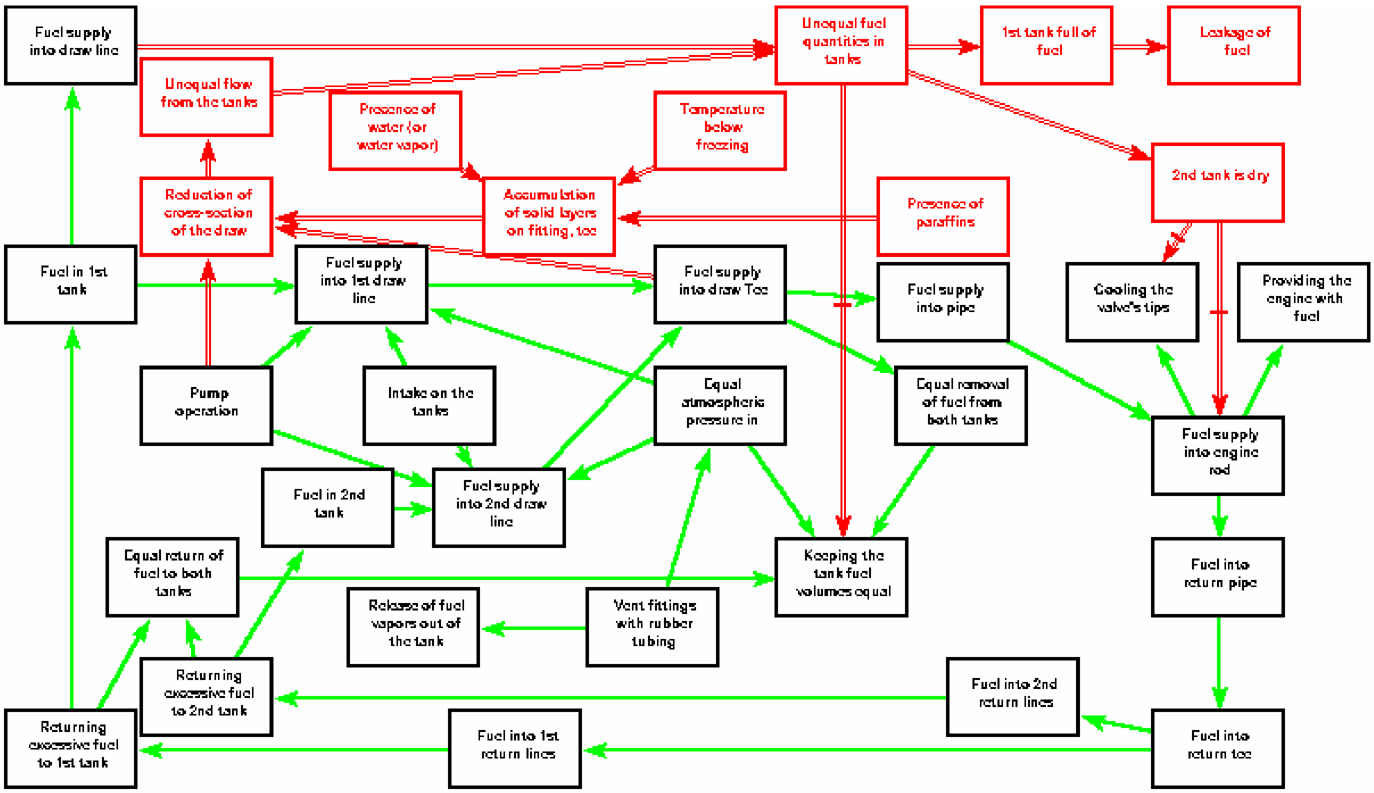


In the case of the presence of water (or water vapors), during cold weather ice will form at the bottom of the tank, because water is heavier than fuel and the bottom of the tank is cooled by the wind during the movement. When the return system supplies warm fuel back to tank, pieces of ice can be removed from the bottom and partially block the draw line. It will cause drawing of different quantities of fuel from the tanks and the accumulation of differences in the fuel levels of the tanks.

If one draw line is partially or completely blocked, less fuel will go from the tank, but the return system will supply fuel continuously. It will cause the drawing of fuel from one tank, and returning it to both with a gradual reduction of fuel level in one of the tanks. At the same time, the temperature of fuel in the tank will be different, because of different amounts of fuel, which was initially in the tank and returned from the engine. The difference in temperatures will cause differences in viscosity, less viscous fuel will be drawn faster and this will cause further accumulation of a difference in levels of fuel in the different tanks.

Imbalance can happen if the vent fitting or rubber tubing of one of the tanks is blocked. In the winter it can be blocked by foreign object (pieces of ice, snow, salt, etc.) or by freezing water in the tubing. This will limit fuel draw from the tank, and will generate gradual accumulation of different tank levels.

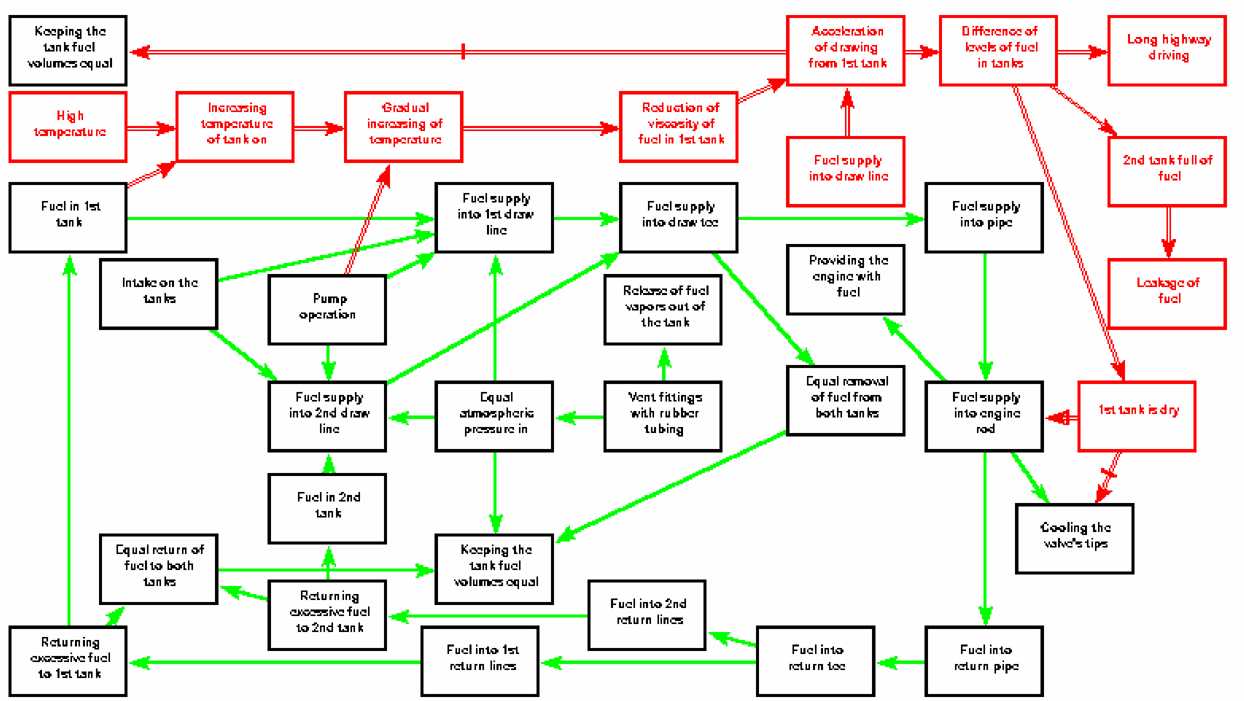
Above-mentioned factors can act alone, but in the case of simultaneous action of a few factors, fuel level imbalance will happen faster.



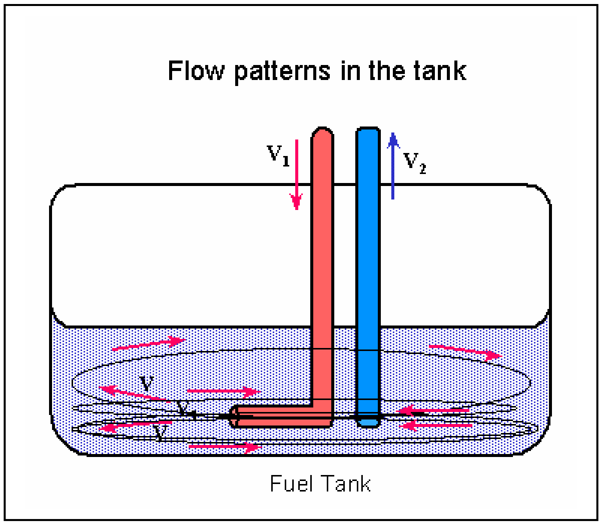
1.1. Low temperature, refueling with summer fuel and prolonged parking of the truck
The prolonged stationary conditions will probably accelerate the imbalance in the system if ice and/or paraffin wax form solid particles during these stationary conditions. Once driving is initiated, all mechanisms of imbalance of the system will be similar to case 1.
1.2. Low temperature, refueling with winter fuel when some amount of summer fuel remains in tanks
After driving is initiated, all mechanisms of imbalance in the system will be similar to case 1. The amount of particles, which can precipitate from the fuel to form solids, will have an impact on the imbalance (but this will probably be small).
1.3. Low temperature and/or wind and/or rain and/or snow from one side during driving. Additional cooling from one side can contribute to the process of accumulation of temperature differences between the tanks. The difference in temperatures will cause a difference in viscosity, less viscous fuel will be drawn faster and this will cause further accumulation of differences in levels of fuel in different tanks.
1.4. Low temperature and heating of one tank by the sun during long periods of driving. Same mechanism as in case 1.3, the only difference beginning in the process, because one tank is warmer than the other.

2. Fuel level imbalance during the summer

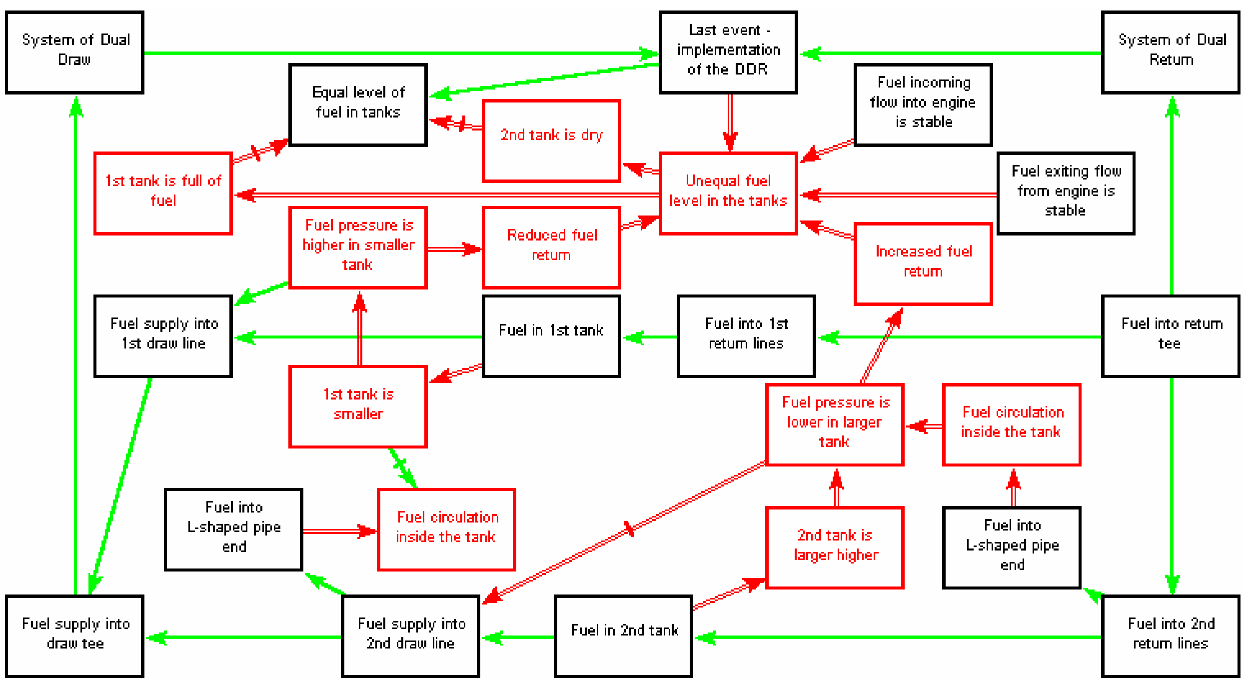
In the case of summer operation in Southern States (such as, Arizona), it is possible to assume, that the temperature in the sun is very different from the temperature in the shade. During continuous driving when the sun is on one side of the truck, the temperature of the tank on the sunny side is much higher, than the tank on the shade side. The difference in the temperatures of the tanks will trigger the process, similar to case 1.4: differences in temperatures will cause a difference in viscosity, a difference in viscosity will cause different rates of drawing the fuel, which will cause an accumulation of differences in levels of fuel in different tanks. In this case high concentrations of different viscosity liquids remaining in the tanks can accelerate the process. Wind from one side can accelerate the process of imbalance in the system, if it comes from the shaded side.



3. Circular flow patterns formed by return flow



Return system provides substantial flow back to the tank. Each minute around 0,4 gallons of the fuel is returned back to tank. This flow can provide flow circulation inside the tank with formation of circular flow patterns. The circular flow patterns can cause an impact on the return flow. If speed of the circular flow is increased, pressure inside the flow is reduced, this enables the easy exiting of the flow from return pipe. This self-supporting amplifying process can cause an increase in return flow to the tank.
Increasing the return flow to the tank causes directing of the majority of the return flow to this tank. The extreme case is directing all of the return flow into one tank and also fuel transfer from one tank to the other. This process can be affected by flow imbalance in the return tee.



It is necessary to define how this effect can take place in one tank with less impact in second tank? The circular flow patterns can be formed or provide a different impact based on different sizes and shapes of the tanks.

In the case of the presence of this mechanism in the fuel system, it would have minimal impact during driving inside the city (because of accelerations, starts, stops and turns to different sides) and would be a greater influence during long highway trips or during long-term parking.

Questions related to hypothesis N3

? What is the source of energy used for fuel pump operation: is it a separate drive or driven from the engine?

? When does fuel pump work at maximum output (RPM)?

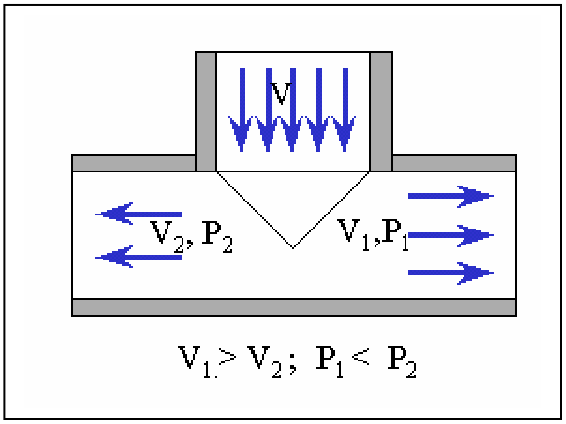
? When does the pump operate without changes in output (RPM)?

? What changes happen to the fuel pump design during the life of the existing design? (Have there been any changes in the pump design (powerful or less powerful)?

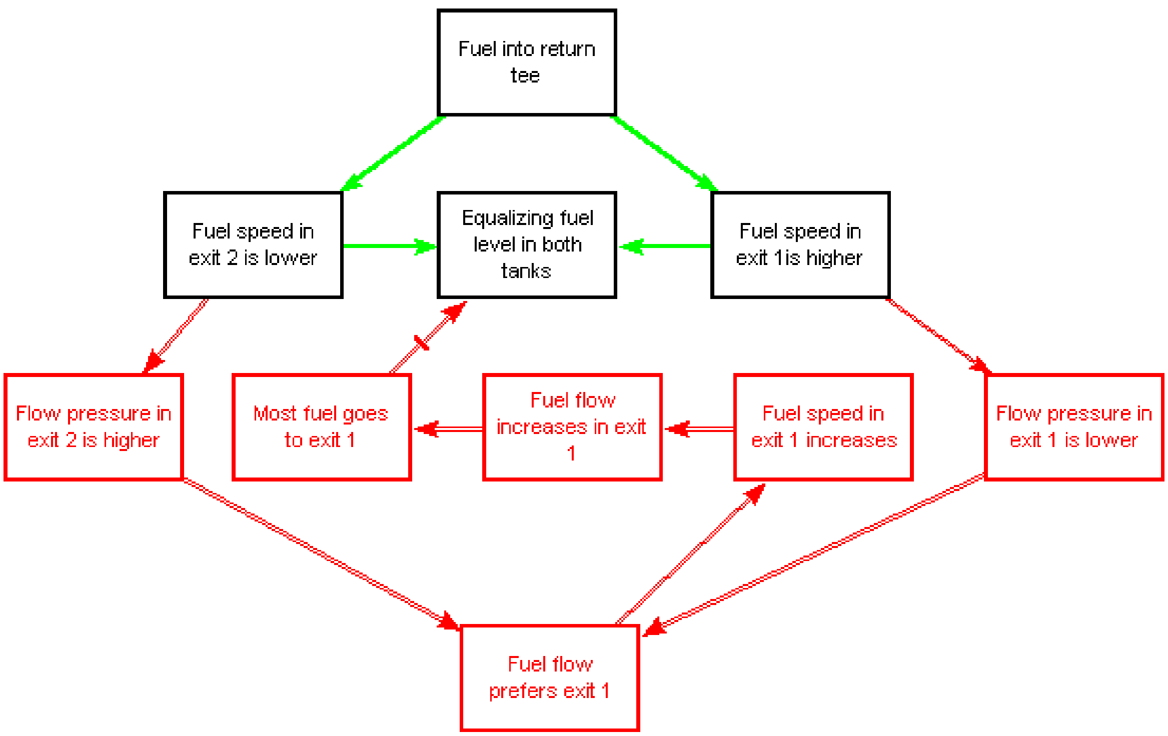
? Have there been any changes of material or diameters of the piping/tubing/connectors in the fuel system?

? Please describe any changes in configuration of return and draw pipes inside the fuel tank during the life of the existing design?

4. Imbalance of the flow in the return tee



Double draw and double return fuel system has to provide different volumes fuel, returned to different tanks. This happens in case of different levels of the fuel in the tanks or two different tanks with same level of the fuel. This means that there are two different flows to different tanks existing at the return tee. Velocity and pressure in these flows are different. If pressure of one flow is lower than in the other, the fuel flow equilibrium will shift to the flow with lower pressure and higher speed.
Increasing of the flow in one side of the tee causes directing of most of the return flow to the corresponding tank. And, the next step, directing of all of the return flow into one of the tanks. Extreme case, is sucking the fuel from other tank.

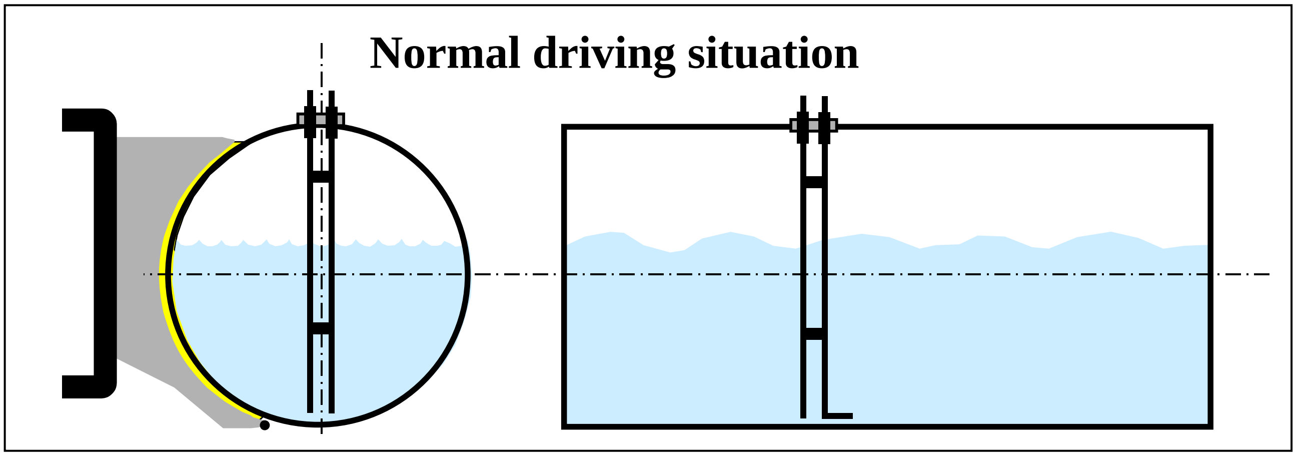


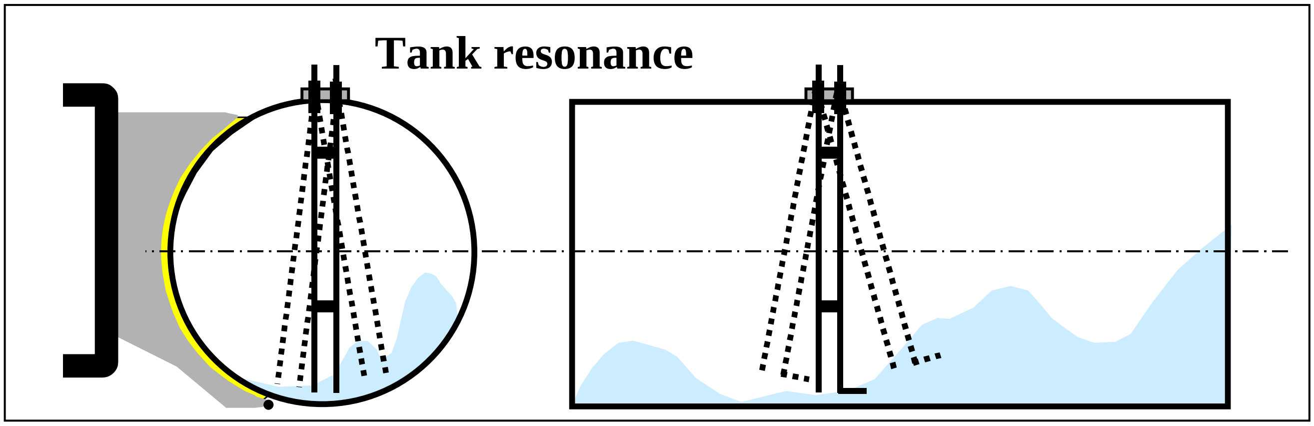
5. Gradual accumulation of differences in the temperatures of the tanks (truck equipped with two different tanks)

The return system supplies hot fuel back to tanks and it is mixed with the fuel in the tank. In the case of different tanks, the fuel in the smaller tank will have a higher temperature. In the case of long trips and recycling of the fuel through the system, differences in temperatures will be accumulated gradually. Cooling of the smaller tank will differ from cooling of the larger tank, because of the differences in surface area.

The viscosity of hot fuel is different, than cold fuel. When the viscosity of fuel is different, the draws from the tanks will be different. Drawing of different amounts of fuel from the tanks will gradually provide different levels of the fuel in tanks.

6. Influence of resonant vibrations





Assumptions:

1. The tank is fixed to brackets via tightening straps that have certain elasticity. An elastic liner is placed between the tank and straps; the tank itself has some elastic property plus it is round and is made from material with certain elasticity. It means that the tank represents an oscillation system which should have a rather low natural frequency (taking in consideration the combined elasticity of tank attachment).
2. It is possible that the resonant frequency of the tank will substantially drop when the straps' tension loosens (for whatever reasons).
3. The resonant frequency of any oscillation system depends on its mass. As a result, the frequencies of tanks with different mass will differ. The different tensions of different straps can also contribute, making the frequencies dependent on different tensions of both straps from the same tank.
4. Because of fuel consumption, the tanks' mass is variable. The frequency will reduce as a function of the reduction of fuel mass, at the same time the efforts required to initiate oscillation is dropping (the resonant frequency may change to a range between several hundreds to several dozens Hertz).
5. Road shocks may create wide range of vibration. The frequency and the magnitude of oscillations are proportional to the speed of driving and depend on road conditions (the worse the road, the higher frequency and magnitude).

6. The truck suspension attachments is working as a filter that dampens certain vibrations and allow the others. It is important to mention that this filtering function is not consistent and is non-linear; it depends on the load.
7. Intake and returning pipes are attached to the tank body.

Conclusions:

During driving a situation may take place when the truck's oscillations come close to the natural frequency of the tank with the remaining fuel. It can happen when the tank contains a relatively small amount of fuel. In this situation the tank oscillations might amplify causing the following effects:

1. Initiation of resonant vibration may force the intake device to dangle inside the tank or oscillate with high frequency both longitudinal and transversal.
2. Strong splashing of the fuel remaining in the tank can stop or weaken the liquid flows.
3. Pipes dangling and fuel splashing may result in increasing the probability of air getting into the pipes that may cause the engine to stop.
4. Substantial amplification of turbulence in pipes and especially in connecting parts can cause 'turbulence crisis' which can stop or seriously decrease flow.
5. Creation of standing waves in pipes can increase turbulence in the loops and impact the liquid flow.
6. Because intake and return pipes have slightly different design, it is possible that the flow may be disturbed in one of them at the time. This may result in two possible scenario:
   - Intake pipe continues working while the return is blocked. The fuel quickly leaves the tank.
   - Intake pipe blocks while the return continues working. The fuel mass in the tank is growing and the tank leaves the resonant zone. The intake pipe starts working again leading to fuel reduction and the process repeats itself. Sooner or later the system occasionally will pass the resonant zone and will start working normally.

7. Integrated effect of the different reasons for failure

There are many irregularities of the fuel system, which can be difficult to control. These irregularities can create difference of the flow in different parts of the system. The following factors can contribute to these irregularities:

- Turbulent or laminar flow in the pipes
- Viscosity of the fuel and its changes due to the temperature of fuel
- Different volume of fuel in the tanks
- Different temperature of fuel in the tanks
- Different weather influences (sun, wind, rain, snow, cold, etc.)
- Different position of the tank on the truck
- Difference of levels of the tanks in cases of side slope or nose up/down position during driving
- Difference of levels of the tanks in cases of side slope or nose up/down position during parking
- Mechanical or manufacturing induced obstruction of the system
- Vibration and resonance of system during truck operation
- Acceleration, stopping and turning, which provide influence on the fuel in tanks
- Different consumption of the fuel by the engine due to road conditions
- Varying output of the pump due to different regimes of the engine

Due to integration of the contributing factors causing failure, eliminating of the factors one-by-one is practically impossible. Therefore, there are following approaches for problem resolution:

- Elimination of most influencing factors
- Compensating of resulting effects of all factors

3.3. Verifying Failure Hypotheses

Information provided by Navistar experts Garry Schaaf and Eric Maxwell served as a basis for elaboration on criteria for preliminary verification of the hypotheses.

Following criteria are used for hypotheses verification:

1. The strongest energy resource in the Dual Draw and Return System is flows of fuel. That is why most the of the probable mechanisms of the hypotheses are the mechanisms, provided by the flow of fuel.
2. Stable flow is required for realization of the hypotheses.
3. Level of the fuel (quantity of fuel in tank) can have substantial influence on the beginning of fuel transfer from one tank to another.
4. The fuel transfer mechanism has to draw the fuel mostly from one tank and return it mostly to another tank for quickest imbalance of the fuel system.
5. All resources required for implementation of the hypotheses have to exist or be available as derivatives from existing resources.

Preliminary verification

Preliminary verification was done on the basis of available information about system resources.

Hypotheses	Resources for realization		Probability of existence		Contribution into harmful effect		Priority for elimination	
	TRIZ	SME	TRIZ	SME	TRIZ	SME	TRIZ	SME
1.Fuel level imbalance in winter (temperature is below freezing point).	Yes		50%		50%		Low	
2. Fuel level imbalance during the summer	Yes		50%		50%		Low	
3. Circular flow patterns formed by return flow	Yes		High		High		High	
4. Imbalance of the flow in return tee	Yes		High		High		High	
5. Gradual accumulation of differences in the temperatures of the tanks (truck equipped with two different tanks)	Yes		50%		50%		Low	
6. Influence of resonant vibrations	Yes		High		High		High	
7. Integrated effect of the different reasons for failure	Yes		High		High		High	

Recommendations for possible tests

Hypothesis N 3. Circular flow patterns formed by return flow

Recommendations for testing:

1. Visual inspection of the flow during engine operation.
2. Creation of the flow in the fuel tank by special pump and testing the performance of the fuel balancing system.
3. Comparison of operation of fuel balance system "as is" and with barriers for prevention of the circular flows inside the tanks.

Hypothesis N 4. Imbalance of the flow in the return tee

Recommendations for testing:

1. Installation of a tee with different diameters on left and right openings and testing the performance of the fuel balancing system.
4. Supply of additional flow into one side of the fuel system after tee. This will create an additional reduction of pressure in this side of the system

Hypothesis N 6. Influence of resonant vibrations.

Recommendations for testing:

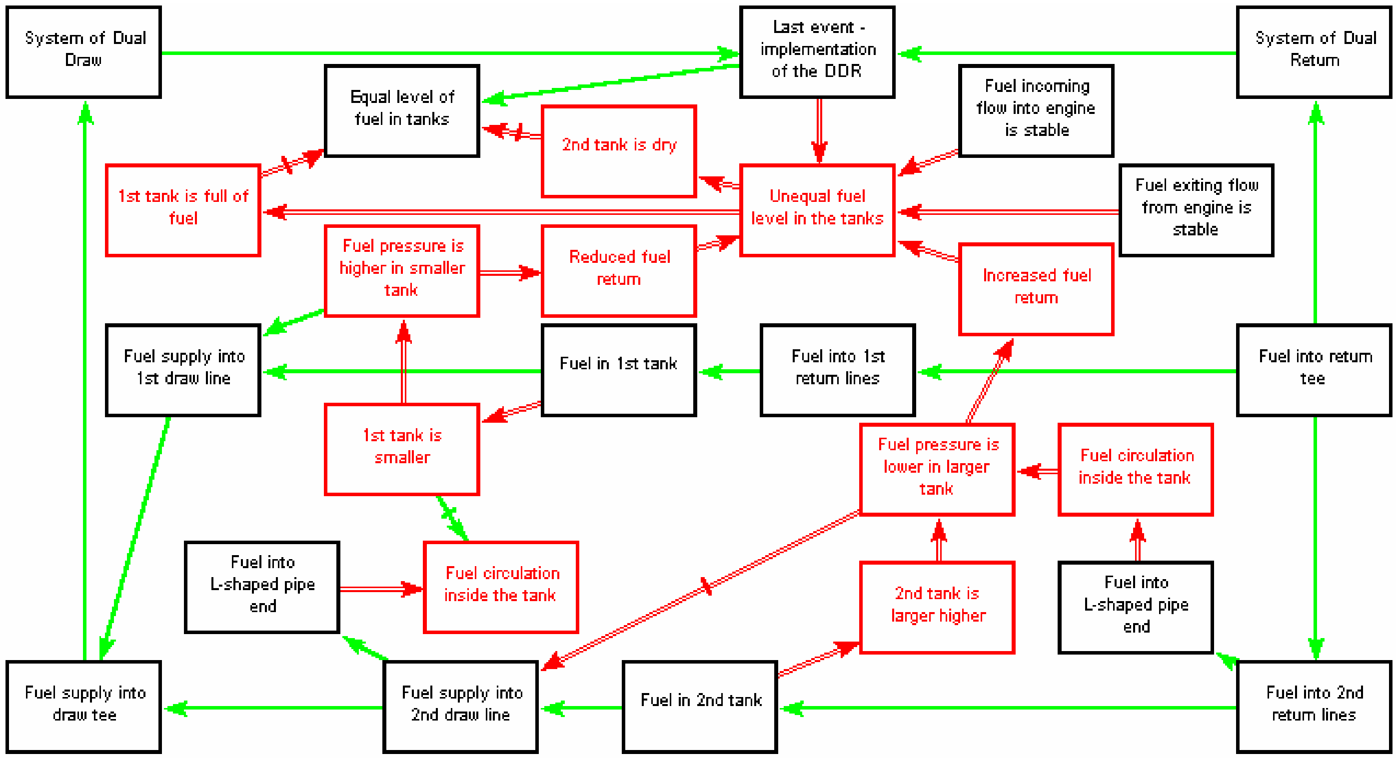
1. Static experiments. Experiments that will confirm or reject the hypothesis can be performed. In static state measurements of the natural frequencies of the fasteners under different amounts of fuel in the tank and different tension of straps.
2. Dynamic experiments. This requires equipping tanks with sensors and recording of vibrations until all fuel is consumed, changing speed of movement and use of different roads. The same experiment should be repeated with loose fasteners. These experiments will provide acquisition of tank oscillation parameters.

Hypothesis N 1. Fuel level imbalance in winter (temperature is below freezing point).

Navistar Report No. Ch-16624: "The evaluation was in response to an American Freightways concern about fuel tank imbalance. American Freightways drivers were noticing that the right tank would overflow on this vehicle and the left tank would consume more fuel. The phenomenon would happen only at night, with the ambient temperature approximately 0^{o}F while driving on the highway".

3.4. Creating the Resulting Failure Diagram (fragment)

According to preliminary verification the following Hypothesis was selected:
Circular flow patterns formed by return flow



4. Preventing or Eliminating Failures

4.1. Prevention Problem Formulation

Anticipatory Failure Determination software was used to generate directions for preventing or eliminating failures. Some are them attached in the appendixes.

See appendix 2: Refined directions for failure elimination for the hypothesis N 3 . (Circular flow patterns formed by return flow.)

See appendix 3:Refined directions for failure elimination for the hypothesis N 4. (Imbalance of the flow in return tee)

Here are selected directions for Failure Prevention or Elimination to diagram above and corresponding operators.

Considering direction:

» 3. Counteract [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).

Considering Operator: Counteracting the harmful effect

Consider eliminating a harmful effect by using another effect.

For this purpose, consider:

- opposing an action that causes a harmful effect with another, similar action
- neutralizing the harmful effect with a countering effect

Considering direction:

»7. Modify or substitute the object, affected by [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).

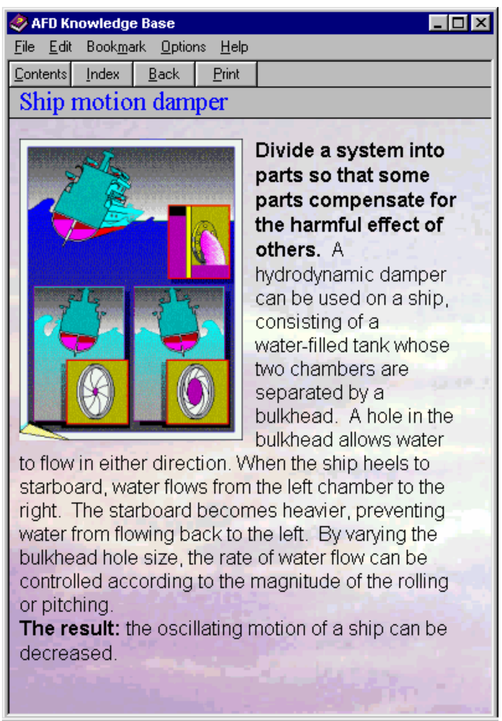
Considering Operator: Modifying or substituting the object effected by harm

If it is impossible to protect the object from the harmful effect, consider changing the object's properties or even substituting the object.

Consider, in particular:

- transforming that portion of the object where the harmful effect is believed to take place
- dividing your object into parts so that some parts will compensate for the harmful effect of the others

Illustration: Ship motion damper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Ship motion damper

Divide a system into parts so that some parts compensate for the harmful effect of others. A hydrodynamic damper can be used on a ship, consisting of a water-filled tank whose two chambers are separated by a bulkhead. A hole in the bulkhead allows water to flow in either direction. When the ship heels to starboard, water flows from the left chamber to the right. The starboard becomes heavier, preventing water from flowing back to the left. By varying the bulkhead hole size, the rate of water flow can be controlled according to the magnitude of the rolling or pitching.

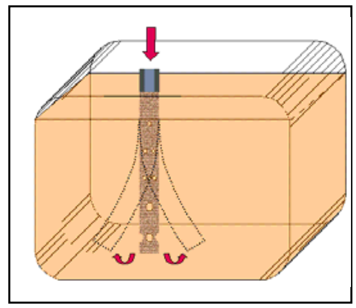
The result: the oscillating motion of a ship can be decreased.

4.2. Prevention Concept Development

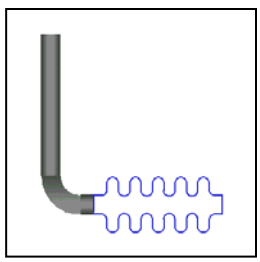
These concepts were generated on the basis of available information and should be assessed and adapted to the current design by Subject Matter Experts.
After joint development of concepts by Subject Matter Experts and TRIZ specialists, there is the possibility that patents can be filed.

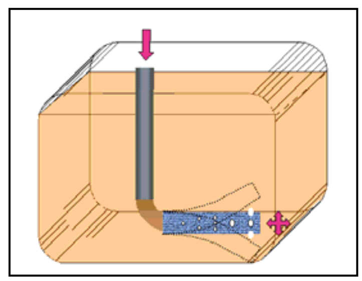
Concepts:
Prevention of the creation of circulation flows in fuel tanks

1. Installation of flexible pipes instead of metal return pipe inside the fuel tank. Flexible pipes will have some chaotic movement inside the fuel tank and prevent establishing of circulating flows inside the fuel tanks.(It is possible to make parts of the pipe flexible from chemical and temperature resistant fabrics)

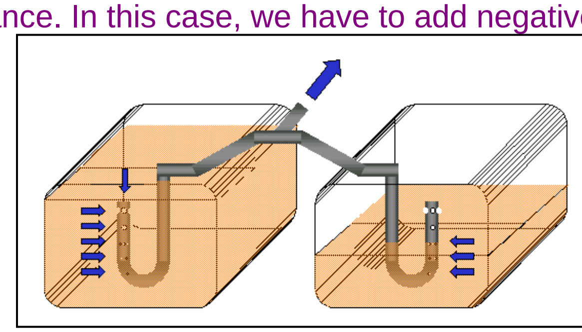


2. Installation of flexible ends on the tips of metal return pipe inside the fuel tank. Flexible ends will have some chaotic movement inside the fuel tank and prevent establishing circulating flows inside the fuel tanks. Flexible or rigid ends can have a special shape for generation of turbulence and reduction of flow energy.





3. Increasing the useful functionality of the balancing system. Let's assume that the fuel system is always in the process of imbalance. In this case, we have to add negative feedback. If there is a higher level of fuel in one tank, the draw system has to take more fuel from this tank and less fuel from the tank with the lower level.

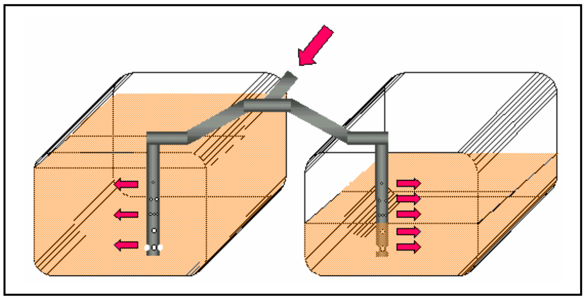


   Installation of U-shaped draw pipe with openings, located on the draw side (see drawing of U-shaped pipes). There are more openings on the higher end of this U-pipe which allows less fuel to be drawn when there is a lower level of the fuel. At the same time resistance to pumping is getting higher with the reduction in the level of fuel. The opposite tank will have a higher level of fuel and more fuel will be drawn from this tank.

4. Increasing the useful functionality of the return system. If there is a higher level of

fuel in one tank, the return system has to return less fuel into this tank and more fuel to the tank with a higher level.

Installation of a return pipe with openings. There are fewer openings on the higher part of the pipe, resistance to pumping is rising with an increase in the level of fuel and less fuel will be pumped where there is a high level of the fuel. The opposite tank will have a lower level of fuel, lower resistance to pumping and more fuel will be pumped into this tank.



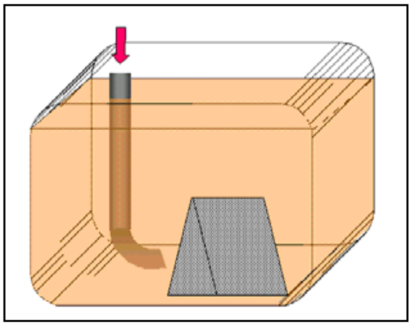
5. Installation of vertical return pipes instead of L-shaped pipes in both tanks and reduction of flow velocity by directing the flow to the bottom of the tank.

6. Introduction of asymmetry. Installation of inclined return pipes in both tanks and a reduction in flow velocity by directing the flow to the bottom of the tank or into the corner of the tank.

7. Return flow without return pipes inside the tanks. This will prevent the flow patterns that may be affecting the incoming and outgoing flows. If it is required, energy of the flow can be reduced by installation of the mesh on the opening.

8. Installation of barriers with openings or specially formed meshes (nets) inside the tank for reduction of the return flow energy.

9. Directing of the return flow on the tank's wall.

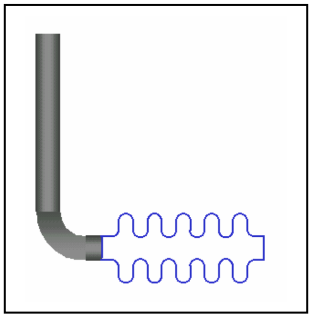


10. Reduction of the flow velocity by installation of a piping with larger diameter than existing one.

11. Installation of U-shaped pipe for the return system. With an increase in the level of fuel in the tank there will be a reduction of the flow energy. Resistance to the return flow will gradually increase.

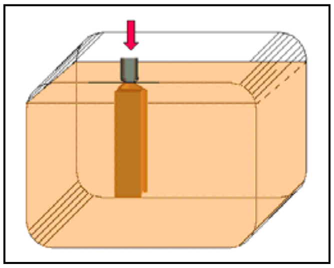
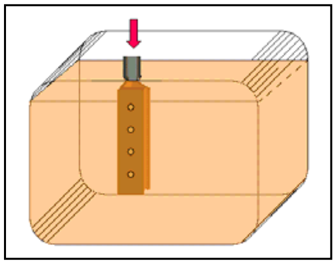
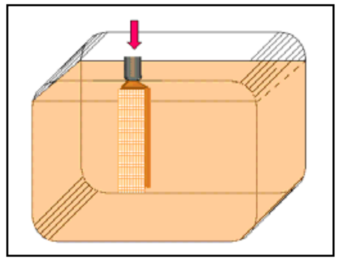
12. Arrangement of few zones with variable (reduced/enlarged) diameter of the L-tube for the creation of turbulence in the return flow and reduction of the flow energy.

13. Transition to return pipe made of formed sheet metal. Complete sealing of the flow in return pipe

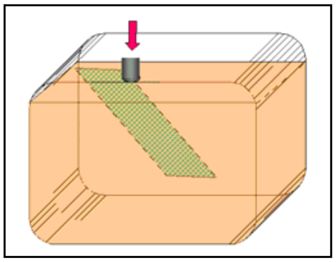
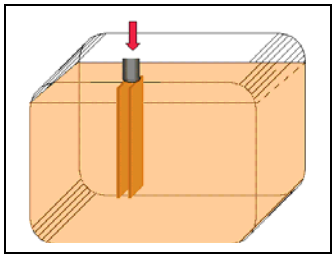
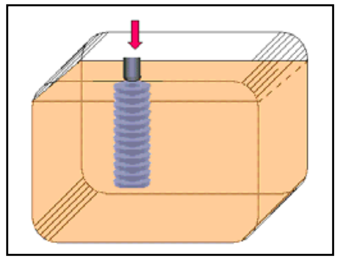


inside the tank is not required because it is located inside the tank.

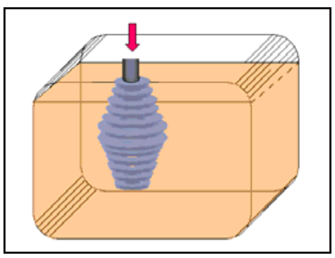
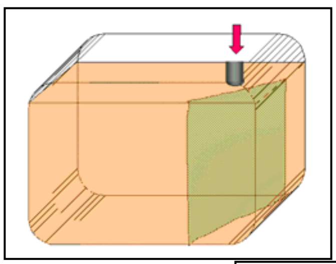
- Strip rolled up in tube shape (cost reduction)
- Strip rolled up in tube with a gap (slot). In this case the flow will be changed in process of filling the tank.
- Utilization of corrugated and perforated strips.

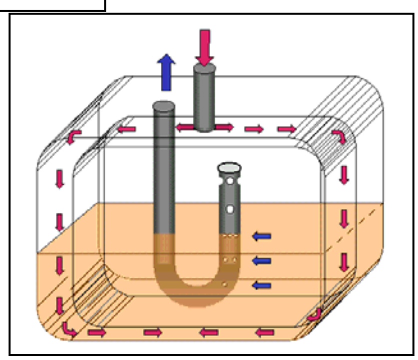
- Utilization of flexible elastic metal sheet.
- Flat tube from two strips. In this case the distance between the strips can be different and this effect can be used for reduction of the flow energy.
- Spiral winding of the strip or wire with openings. Diameter of produced pipe can be changed along the length of the pipe.

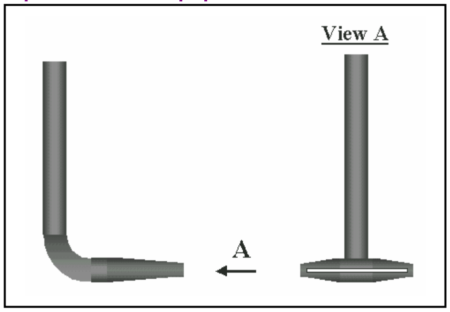
- Installation of a sheet along the side of the tank or corner of the tank.

- Rolled sheet with arrangement of the flow along the surface. The sheet can be corrugated or with openings for reduction of flow energy. Sheet, arranging two flows in opposite directions with reduction of the flow energy by merging the flows.

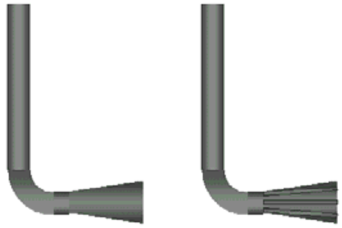


14. Application of special shapes at the tips of L-shaped return pipes:
    - Flat tip made by squeezing of the same pipe with slit opening on the end
    - Flat tip with slit with a few openings
    - "Shower" tip with net on the opening. The "shower" can be directed up.



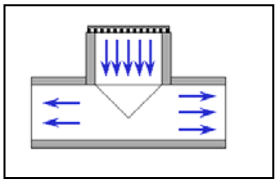
- Openings on the horizontal end of the pipe. The openings can be round or flat.

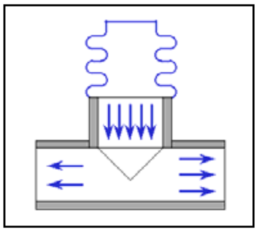
- Openings with bent strips on the ends of the pipe. The strips can be bent inside or outside the pipe. The bent strips can together form different shapes, i.e. shape of the funnel can be used for reduction of return flow energy.



Prevention of flow imbalance in tee

1. Installation of spiral, net or other insertion before entering into return tee for destabilization of the flow in the tee.





2. Introduction of diffuser for air accesses before tee.

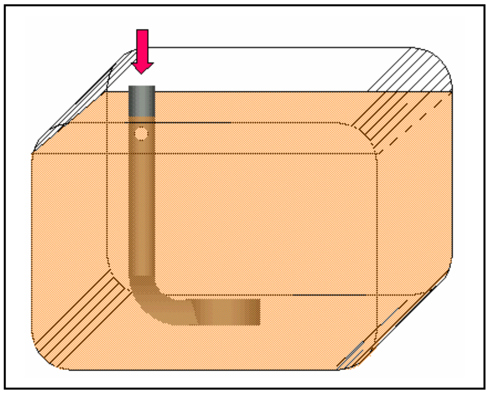
3. Installation of one or more flexible strips at the tee's entry for the destabilization of the flow.

4. Location of return tee inside the tank. Opening in the entry part of the tee for prevention of flow, in one direction.

Reduction in imbalance of the system during operation under side slope conditions and nose up/down situations

Concept N 3 and 4 of the previous paragraph slow down siphoning in the case of side slope conditions. At the same time upon beginning driving the fuel from tank with the higher level is drawing more intensively. This can partially resolve the problem.

1. Small opening on the top of the return L-tube. During parking on the side slop with stopped engine this will eliminate siphoning through return line.



2. Installation of shorter return L-tubes.

3. Installation of U-shaped tubes for draw system will reduce the drawing from the tank with the lower level of fuel in the tank.

4. Relocation of return and draw tees to a higher level above the tanks

5. Utilization of resources of pressurized air for equalization of fuel levels. This solution can be used for existing design when a truck is left on a hill overnight and the fuel tanks siphon from one tank to the other. Fuel can be forced from one tank to another by the resource of pressurized air.

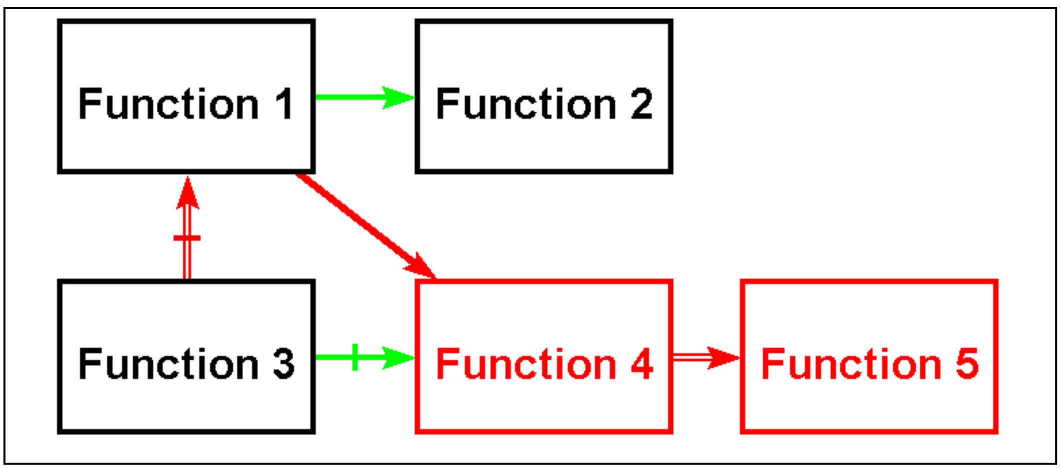
Prevention of Influence from resonant vibration

1. If one tank becomes empty, it is necessary to check fasteners' tension and tighten straps on both tanks. This may eliminate the harmful effect.

Appendix 1. Formulation Graph Building.

Building the Formulation Graph is a very important stage of work in searching for mechanisms of undesired effects. After data collection and systematization of key information, translation of information to the "TRIZ language" is required to ensure efficient utilization of the tools of Anticipatory Failure Determination. The translation is provided by means of an artificial intelligence system called the "Problem Formulator". The user creates a cause-effect description of the system in the form of a graph, which is converted by the Problem Formulator into Problem Statements.

Typical Graphical Descriptions of a Problem Situation include different functions and standard links between the functions.



This Graph describes the following Problem Situation:

- ([Useful] Function 1) provides ([Useful] Function 2)
- ([Useful] Function 1) causes ([Harmful] Function 4)
- ([Useful] Function 3) eliminates ([Harmful] Function 4)
- ([Useful] Function 3) hinders ([Useful] Function 1)
- ([Harmful] Function 4) causes ([Harmful] Function 5)

Appendix 2. Refined directions for failure elimination for hypothesis N 3 . (Circular flow patterns formed by return flow):

The Anticipatory Failure Determination software generates directions for preventing or eliminating failures. Samples of the directions are shown below.

1. Isolate [the] (Fuel supply into 2nd draw line) from the hindering action of [the] (Fuel pressure is lower in larger tank).
2. Increase the resistance of [the] (Fuel supply into 2nd draw line) to the hindering action of [the] (Fuel pressure is lower in larger tank).
3. 'Defend' [the] (Fuel supply into 2nd draw line) by changing the source of [the] (Fuel pressure is lower in larger tank).
4. Support [the] (Fuel supply into 2nd draw line) by modifying the harmful effect of [the] (Fuel pressure is lower in larger tank).
5. Increase the effectiveness of [the] (Fuel supply into 2nd draw line) by counteracting the harmful effect of [the] (Fuel pressure is lower in larger tank).
6. Remove or change the source of [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
7. Modify the effect of [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
8. Counteract [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
9. Isolate the system from [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
10. Avert the causes of [the](Unequal fuel level in the tanks).
11. Increase the system's resistance to [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
12. Modify or substitute the object, affected by [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
13. Localize the harmful effect of [the](Unequal fuel level in the tanks).
14. Reduce the harmful effect of [the](Unequal fuel level in the tanks).
15. 'Blend in' defects caused by [the](Unequal fuel level in the tanks).
16. Consider transient (temporary) use of the harmful effect of [the](Unequal fuel level in the tanks).
17. Facilitate detection of [the](Unequal fuel level in the tanks) that is caused by [the] (Reduced fuel return), (Increased fuel return), (Last event - implementation of the DDR System), (Fuel incoming flow into engine is stable), and (Fuel exiting flow from engine is stable), to eliminate the harmful effect in a timely manner.
18. 'Sugar coat' the harmful effect of the [the](Unequal fuel level in the tanks), if there are no other means to deal with it.
19. Remove or change the source of [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
20. Modify the effect of [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
21. Counteract [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).

22. Isolate the system from [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
23. Avert the causes of [the](1st tank is full of fuel).
24. Increase the system's resistance to [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
25. Modify or substitute the object, affected by [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
26. Localize the harmful effect of [the](1st tank is full of fuel).
27. Reduce the harmful effect of [the](1st tank is full of fuel).
28. 'Blend in' defects caused by [the](1st tank is full of fuel).
29. Consider transient (temporary) use of the harmful effect of [the](1st tank is full of fuel).
30. Facilitate detection of [the](1st tank is full of fuel) that is caused by [the] (Unequal fuel level in the tanks), to eliminate the harmful effect in a timely manner.
31. 'Sugar coat' the harmful effect of the [the](1st tank is full of fuel), if there are no other means to deal with it.
32. Remove or change the source of [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
33. Modify the effect of [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
34. Counteract [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
35. Isolate the system from [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
36. Avert the causes of [the](2nd tank is dry).
37. Increase the system's resistance to [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
38. Modify or substitute the object, affected by [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
39. Localize the harmful effect of [the](2nd tank is dry).
40. Reduce the harmful effect of [the](2nd tank is dry).
41. 'Blend in' defects caused by [the](2nd tank is dry).
42. Consider transient (temporary) use of the harmful effect of [the](2nd tank is dry).
43. Facilitate detection of [the](2nd tank is dry) that is caused by [the] (Unequal fuel level in the tanks), to eliminate the harmful effect in a timely manner.
44. 'Sugar coat' the harmful effect of the [the](2nd tank is dry), if there are no other means to deal with it.
45. Isolate [the] (Equal level of fuel in tanks) from the hindering action of [the] (2nd tank is dry) and (1st tank is full of fuel).
46. Increase the resistance of [the] (Equal level of fuel in tanks) to the hindering action of [the] (2nd tank is dry) and (1st tank is full of fuel).
47. 'Defend' [the] (Equal level of fuel in tanks) by changing the source of [the] (2nd tank is dry) and (1st tank is full of fuel).
48. Support [the] (Equal level of fuel in tanks) by modifying the harmful effect of [the] (2nd tank is dry) and (1st tank is full of fuel).
49. Increase the effectiveness of [the] (Equal level of fuel in tanks) by counteracting the harmful effect of [the] (2nd tank is dry) and (1st tank is full of fuel).

50. Remove or change the source of [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
51. Modify the effect of [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
52. Counteract [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
53. Isolate the system from [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
54. Avert the causes of [the](Fuel circulation inside the tank).
55. Increase the system's resistance to [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
56. Modify or substitute the object, affected by [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
57. Localize the harmful effect of [the](Fuel circulation inside the tank).
58. Reduce the harmful effect of [the](Fuel circulation inside the tank).
59. 'Blend in' defects caused by [the](Fuel circulation inside the tank).
60. Consider transient (temporary) use of the harmful effect of [the](Fuel circulation inside the tank).
61. Facilitate detection of [the](Fuel circulation inside the tank) that is caused by [the] (Fuel into L-shaped pipe end), to eliminate the harmful effect in a timely manner.
62. 'Sugar coat' the harmful effect of the [the](Fuel circulation inside the tank), if there are no other means to deal with it.
63. Remove or change the source of [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
64. Modify the effect of [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
65. Counteract [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
66. Isolate the system from [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
67. Avert the causes of [the](Fuel pressure is lower in larger tank).
68. Increase the system's resistance to [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
69. Modify or substitute the object, affected by [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
70. Localize the harmful effect of [the](Fuel pressure is lower in larger tank).
71. Reduce the harmful effect of [the](Fuel pressure is lower in larger tank).
72. 'Blend in' defects caused by [the](Fuel pressure is lower in larger tank).
73. Consider transient (temporary) use of the harmful effect of [the](Fuel pressure is lower in larger tank).
74. Facilitate detection of [the](Fuel pressure is lower in larger tank) that is caused by [the] (Fuel circulation inside the tank) and (2nd tank is larger higher), to eliminate the harmful effect in a timely manner.

75. 'Sugar coat' the harmful effect of the [the](Fuel pressure is lower in larger tank), if there are no other means to deal with it.
76. Remove or change the source of [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
77. Modify the effect of [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
78. Counteract [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
79. Isolate the system from [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
80. Avert the causes of [the](2nd tank is larger higher).
81. Increase the system's resistance to [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
82. Modify or substitute the object, affected by [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
83. Localize the harmful effect of [the](2nd tank is larger higher).
84. Reduce the harmful effect of [the](2nd tank is larger higher).
85. 'Blend in' defects caused by [the](2nd tank is larger higher).
86. Consider transient (temporary) use of the harmful effect of [the](2nd tank is larger higher).
87. Facilitate detection of [the](2nd tank is larger higher) that is caused by [the] (Fuel in 2nd tank), to eliminate the harmful effect in a timely manner.
88. 'Sugar coat' the harmful effect of the [the](2nd tank is larger higher), if there are no other means to deal with it.
89. Remove or change the source of [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
90. Modify the effect of [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
91. Counteract [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
92. Isolate the system from [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
93. Avert the causes of [the](Increased fuel return).
94. Increase the system's resistance to [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
95. Modify or substitute the object, affected by [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
96. Localize the harmful effect of [the](Increased fuel return).
97. Reduce the harmful effect of [the](Increased fuel return).
98. 'Blend in' defects caused by [the](Increased fuel return).
99. Consider transient (temporary) use of the harmful effect of [the](Increased fuel return).
100. Facilitate detection of [the](Increased fuel return) that is caused by [the] (Fuel pressure is lower in larger tank), to eliminate the harmful effect in a timely manner.
101. 'Sugar coat' the harmful effect of the [the](Increased fuel return), if there are no other means to deal with it.
102. Avert the causes of [the](Fuel circulation inside the tank).
103. Localize the harmful effect of [the](Fuel circulation inside the tank).

104. Reduce the harmful effect of [the](Fuel circulation inside the tank).
105. 'Blend in' defects caused by [the](Fuel circulation inside the tank).
106. Consider transient (temporary) use of the harmful effect of [the](Fuel circulation inside the tank).
107. Facilitate detection of [the](Fuel circulation inside the tank) that is caused by [the](Fuel into L-shaped pipe end), to eliminate the harmful effect in a timely manner.
108. 'Sugar coat' the harmful effect of the [the](Fuel circulation inside the tank), if there are no other means to deal with it.
109. Modify or substitute the object, affected by [the](Fuel circulation inside the tank) to eliminate the harmful effect more effectively than through [the](1st tank is smaller).
110. Increase the system's resistance to [the](Fuel circulation inside the tank) to provide the system with better protection than through [the](1st tank is smaller).
111. Isolate the system from [the](Fuel circulation inside the tank) to provide the system with better protection than through [the](1st tank is smaller).
112. Counteract [the](Fuel circulation inside the tank) to eliminate the harmful effect more effectively than through [the](1st tank is smaller).
113. Modify the effect of [the](Fuel circulation inside the tank) to eliminate it more effectively than through [the](1st tank is smaller).
114. Remove or change the source of [the](Fuel circulation inside the tank) to eliminate the harmful effect more effectively than through [the](1st tank is smaller).
115. Cease or eliminate [the](Fuel circulation inside the tank) by modifying the harmful effect of [the](Fuel into L-shaped pipe end).
116. Neutralize [the](Fuel circulation inside the tank) by counteracting the harmful effect of [the](Fuel into L-shaped pipe end).
117. Remove or change the source of [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
118. Modify the effect of [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
119. Counteract [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
120. Isolate the system from [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
121. Avert the causes of [the](1st tank is smaller).
122. Increase the system's resistance to [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
123. Modify or substitute the object, affected by [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
124. Localize the harmful effect of [the](1st tank is smaller).
125. Reduce the harmful effect of [the](1st tank is smaller).
126. 'Blend in' defects caused by [the](1st tank is smaller).
127. Consider transient (temporary) use of the harmful effect of [the](1st tank is smaller).
128. Facilitate detection of [the](1st tank is smaller) that is caused by [the] (Fuel in 1st tank), to eliminate the harmful effect in a timely manner.
129. 'Sugar coat' the harmful effect of the [the](1st tank is smaller), if there are no other means to deal with it.
130. Remove or change the source of [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).

131. Modify the effect of [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
132. Counteract [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
133. Isolate the system from [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
134. Avert the causes of [the](Fuel pressure is higher in smaller tank).
135. Increase the system's resistance to [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
136. Modify or substitute the object, affected by [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
137. Localize the harmful effect of [the](Fuel pressure is higher in smaller tank).
138. Reduce the harmful effect of [the](Fuel pressure is higher in smaller tank).
139. 'Blend in' defects caused by [the](Fuel pressure is higher in smaller tank).
140. Consider transient (temporary) use of the harmful effect of [the](Fuel pressure is higher in smaller tank).
141. Facilitate detection of [the](Fuel pressure is higher in smaller tank) that is caused by [the] (1st tank is smaller), to eliminate the harmful effect in a timely manner.
142. 'Sugar coat' the harmful effect of the [the](Fuel pressure is higher in smaller tank), if there are no other means to deal with it.
143. Remove or change the source of [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
144. Modify the effect of [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
145. Counteract [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
146. Isolate the system from [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
147. Avert the causes of [the](Reduced fuel return).
148. Increase the system's resistance to [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
149. Modify or substitute the object, affected by [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
150. Localize the harmful effect of [the](Reduced fuel return).
151. Reduce the harmful effect of [the](Reduced fuel return).
152. 'Blend in' defects caused by [the](Reduced fuel return).
153. Consider transient (temporary) use of the harmful effect of [the](Reduced fuel return).
154. Facilitate detection of [the](Reduced fuel return) that is caused by [the] (Fuel pressure is higher in smaller tank), to eliminate the harmful effect in a timely manner.
155. 'Sugar coat' the harmful effect of the [the](Reduced fuel return), if there are no other means to deal with it.

Appendix 3.

Refined directions for failure elimination for hypothesis N 4. (Imbalance of the flow in return tee):

1. Isolate [the] (Fuel supply into 2nd draw line) from the hindering action of [the] (Fuel pressure is lower in larger tank).
2. Increase the resistance of [the] (Fuel supply into 2nd draw line) to the hindering action of [the] (Fuel pressure is lower in larger tank).
3. 'Defend' [the] (Fuel supply into 2nd draw line) by changing the source of [the] (Fuel pressure is lower in larger tank).
4. Support [the] (Fuel supply into 2nd draw line) by modifying the harmful effect of [the] (Fuel pressure is lower in larger tank).
5. Increase the effectiveness of [the] (Fuel supply into 2nd draw line) by counteracting the harmful effect of [the] (Fuel pressure is lower in larger tank).
6. Remove or change the source of [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
7. Modify the effect of [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
8. Counteract [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
9. Isolate the system from [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
10. Avert the causes of [the](Unequal fuel level in the tanks).
11. Increase the system's resistance to [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
12. Modify or substitute the object, affected by [the] (Unequal fuel level in the tanks) to prevent [the] (2nd tank is dry) and (1st tank is full of fuel).
13. Localize the harmful effect of [the](Unequal fuel level in the tanks).
14. Reduce the harmful effect of [the](Unequal fuel level in the tanks).
15. 'Blend in' defects caused by [the](Unequal fuel level in the tanks).
16. Consider transient (temporary) use of the harmful effect of [the](Unequal fuel level in the tanks).
17. Facilitate detection of [the](Unequal fuel level in the tanks) that is caused by [the] (Reduced fuel return), (Increased fuel return), (Last event - implementation of the DDR System), (Fuel incoming flow into engine is stable), and (Fuel exiting flow from engine is stable), to eliminate the harmful effect in a timely manner.
18. 'Sugar coat' the harmful effect of the [the](Unequal fuel level in the tanks), if there are no other means to deal with it.
19. Remove or change the source of [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
20. Modify the effect of [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
21. Counteract [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
22. Isolate the system from [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
23. Avert the causes of [the](1st tank is full of fuel).

24. Increase the system's resistance to [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
25. Modify or substitute the object, affected by [the] (1st tank is full of fuel) to stop the hindering of [the] (Equal level of fuel in tanks).
26. Localize the harmful effect of [the](1st tank is full of fuel).
27. Reduce the harmful effect of [the](1st tank is full of fuel).
28. 'Blend in' defects caused by [the](1st tank is full of fuel).
29. Consider transient (temporary) use of the harmful effect of [the](1st tank is full of fuel).
30. Facilitate detection of [the](1st tank is full of fuel) that is caused by [the] (Unequal fuel level in the tanks), to eliminate the harmful effect in a timely manner.
31. 'Sugar coat' the harmful effect of the [the](1st tank is full of fuel), if there are no other means to deal with it.
32. Remove or change the source of [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
33. Modify the effect of [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
34. Counteract [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
35. Isolate the system from [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
36. Avert the causes of [the](2nd tank is dry).
37. Increase the system's resistance to [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
38. Modify or substitute the object, affected by [the] (2nd tank is dry) to stop the hindering of [the] (Equal level of fuel in tanks).
39. Localize the harmful effect of [the](2nd tank is dry).
40. Reduce the harmful effect of [the](2nd tank is dry).
41. 'Blend in' defects caused by [the](2nd tank is dry).
42. Consider transient (temporary) use of the harmful effect of [the](2nd tank is dry).
43. Facilitate detection of [the](2nd tank is dry) that is caused by [the] (Unequal fuel level in the tanks), to eliminate the harmful effect in a timely manner.
44. 'Sugar coat' the harmful effect of the [the](2nd tank is dry), if there are no other means to deal with it.
45. Isolate [the] (Equal level of fuel in tanks) from the hindering action of [the] (2nd tank is dry) and (1st tank is full of fuel).
46. Increase the resistance of [the] (Equal level of fuel in tanks) to the hindering action of [the] (2nd tank is dry) and (1st tank is full of fuel).
47. 'Defend' [the] (Equal level of fuel in tanks) by changing the source of [the] (2nd tank is dry) and (1st tank is full of fuel).
48. Support [the] (Equal level of fuel in tanks) by modifying the harmful effect of [the] (2nd tank is dry) and (1st tank is full of fuel).
49. Increase the effectiveness of [the] (Equal level of fuel in tanks) by counteracting the harmful effect of [the] (2nd tank is dry) and (1st tank is full of fuel).
50. Remove or change the source of [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
51. Modify the effect of [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).

52. Counteract [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
53. Isolate the system from [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
54. Avert the causes of [the](Fuel circulation inside the tank).
55. Increase the system's resistance to [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
56. Modify or substitute the object, affected by [the] (Fuel circulation inside the tank) to prevent [the] (Fuel pressure is lower in larger tank).
57. Localize the harmful effect of [the](Fuel circulation inside the tank).
58. Reduce the harmful effect of [the](Fuel circulation inside the tank).
59. 'Blend in' defects caused by [the](Fuel circulation inside the tank).
60. Consider transient (temporary) use of the harmful effect of [the](Fuel circulation inside the tank).
61. Facilitate detection of [the](Fuel circulation inside the tank) that is caused by [the] (Fuel into L-shaped pipe end), to eliminate the harmful effect in a timely manner.
62. 'Sugar coat' the harmful effect of the [the](Fuel circulation inside the tank), if there are no other means to deal with it.
63. Remove or change the source of [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
64. Modify the effect of [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
65. Counteract [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
66. Isolate the system from [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
67. Avert the causes of [the](Fuel pressure is lower in larger tank).
68. Increase the system's resistance to [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
69. Modify or substitute the object, affected by [the] (Fuel pressure is lower in larger tank) to prevent [the] (Increased fuel return), and to stop the hindering of [the] (Fuel supply into 2nd draw line).
70. Localize the harmful effect of [the](Fuel pressure is lower in larger tank).
71. Reduce the harmful effect of [the](Fuel pressure is lower in larger tank).
72. 'Blend in' defects caused by [the](Fuel pressure is lower in larger tank).
73. Consider transient (temporary) use of the harmful effect of [the](Fuel pressure is lower in larger tank).
74. Facilitate detection of [the](Fuel pressure is lower in larger tank) that is caused by [the] (Fuel circulation inside the tank) and (2nd tank is larger higher), to eliminate the harmful effect in a timely manner.
75. 'Sugar coat' the harmful effect of the [the](Fuel pressure is lower in larger tank), if there are no other means to deal with it.
76. Remove or change the source of [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).

77. Modify the effect of [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
78. Counteract [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
79. Isolate the system from [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
80. Avert the causes of [the](2nd tank is larger higher).
81. Increase the system's resistance to [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
82. Modify or substitute the object, affected by [the] (2nd tank is larger higher) to prevent [the] (Fuel pressure is lower in larger tank).
83. Localize the harmful effect of [the](2nd tank is larger higher).
84. Reduce the harmful effect of [the](2nd tank is larger higher).
85. 'Blend in' defects caused by [the](2nd tank is larger higher).
86. Consider transient (temporary) use of the harmful effect of [the](2nd tank is larger higher).
87. Facilitate detection of [the](2nd tank is larger higher) that is caused by [the] (Fuel in 2nd tank), to eliminate the harmful effect in a timely manner.
88. 'Sugar coat' the harmful effect of the [the](2nd tank is larger higher), if there are no other means to deal with it.
89. Remove or change the source of [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
90. Modify the effect of [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
91. Counteract [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
92. Isolate the system from [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
93. Avert the causes of [the](Increased fuel return).
94. Increase the system's resistance to [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
95. Modify or substitute the object, affected by [the] (Increased fuel return) to prevent [the] (Unequal fuel level in the tanks).
96. Localize the harmful effect of [the](Increased fuel return).
97. Reduce the harmful effect of [the](Increased fuel return).
98. 'Blend in' defects caused by [the](Increased fuel return).
99. Consider transient (temporary) use of the harmful effect of [the](Increased fuel return).
100. Facilitate detection of [the](Increased fuel return) that is caused by [the] (Fuel pressure is lower in larger tank), to eliminate the harmful effect in a timely manner.
101. 'Sugar coat' the harmful effect of the [the](Increased fuel return), if there are no other means to deal with it.
102. Avert the causes of [the](Fuel circulation inside the tank).
103. Localize the harmful effect of [the](Fuel circulation inside the tank).
104. Reduce the harmful effect of [the](Fuel circulation inside the tank).
105. 'Blend in' defects caused by [the](Fuel circulation inside the tank).
106. Consider transient (temporary) use of the harmful effect of [the](Fuel circulation inside the tank).

107. Facilitate detection of [the](Fuel circulation inside the tank) that is caused by [the](Fuel into L-shaped pipe end), to eliminate the harmful effect in a timely manner.
108. 'Sugar coat' the harmful effect of the [the](Fuel circulation inside the tank), if there are no other means to deal with it.
109. Modify or substitute the object, affected by [the](Fuel circulation inside the tank) to eliminate the harmful effect more effectively than through [the](1st tank is smaller).
110. Increase the system's resistance to [the](Fuel circulation inside the tank) to provide the system with better protection than through [the](1st tank is smaller).
111. Isolate the system from [the](Fuel circulation inside the tank) to provide the system with better protection than through [the](1st tank is smaller).
112. Counteract [the](Fuel circulation inside the tank) to eliminate the harmful effect more effectively than through [the](1st tank is smaller).
113. Modify the effect of [the](Fuel circulation inside the tank) to eliminate it more effectively than through [the](1st tank is smaller).
114. Remove or change the source of [the](Fuel circulation inside the tank) to eliminate the harmful effect more effectively than through [the](1st tank is smaller).
115. Cease or eliminate [the](Fuel circulation inside the tank) by modifying the harmful effect of [the](Fuel into L-shaped pipe end).
116. Neutralize [the](Fuel circulation inside the tank) by counteracting the harmful effect of [the](Fuel into L-shaped pipe end).
117. Remove or change the source of [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
118. Modify the effect of [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
119. Counteract [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
120. Isolate the system from [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
121. Avert the causes of [the](1st tank is smaller).
122. Increase the system's resistance to [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
123. Modify or substitute the object, affected by [the] (1st tank is smaller) to prevent [the] (Fuel pressure is higher in smaller tank).
124. Localize the harmful effect of [the](1st tank is smaller).
125. Reduce the harmful effect of [the](1st tank is smaller).
126. 'Blend in' defects caused by [the](1st tank is smaller).
127. Consider transient (temporary) use of the harmful effect of [the](1st tank is smaller).
128. Facilitate detection of [the](1st tank is smaller) that is caused by [the] (Fuel in 1st tank), to eliminate the harmful effect in a timely manner.
129. 'Sugar coat' the harmful effect of the [the](1st tank is smaller), if there are no other means to deal with it.
130. Remove or change the source of [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
131. Modify the effect of [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
132. Counteract [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).

133. Isolate the system from [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
134. Avert the causes of [the](Fuel pressure is higher in smaller tank).
135. Increase the system's resistance to [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
136. Modify or substitute the object, affected by [the] (Fuel pressure is higher in smaller tank) to prevent [the] (Reduced fuel return).
137. Localize the harmful effect of [the](Fuel pressure is higher in smaller tank).
138. Reduce the harmful effect of [the](Fuel pressure is higher in smaller tank).
139. 'Blend in' defects caused by [the](Fuel pressure is higher in smaller tank).
140. Consider transient (temporary) use of the harmful effect of [the](Fuel pressure is higher in smaller tank).
141. Facilitate detection of [the](Fuel pressure is higher in smaller tank) that is caused by [the] (1st tank is smaller), to eliminate the harmful effect in a timely manner.
142. 'Sugar coat' the harmful effect of the [the](Fuel pressure is higher in smaller tank), if there are no other means to deal with it.
143. Remove or change the source of [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
144. Modify the effect of [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
145. Counteract [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
146. Isolate the system from [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
147. Avert the causes of [the](Reduced fuel return).
148. Increase the system's resistance to [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
149. Modify or substitute the object, affected by [the] (Reduced fuel return) to prevent [the] (Unequal fuel level in the tanks).
150. Localize the harmful effect of [the](Reduced fuel return).
151. Reduce the harmful effect of [the](Reduced fuel return).
152. 'Blend in' defects caused by [the](Reduced fuel return).
153. Consider transient (temporary) use of the harmful effect of [the](Reduced fuel return).
154. Facilitate detection of [the](Reduced fuel return) that is caused by [the] (Fuel pressure is higher in smaller tank), to eliminate the harmful effect in a timely manner.
155. 'Sugar coat' the harmful effect of the [the](Reduced fuel return), if there are no other means to deal with it.