

SNAP CODES: 050500
050501
050502
050503

SOURCE ACTIVITY TITLES: GASOLINE DISTRIBUTION
*Refinery Dispatch Station
Transport and Depots (Except 050503)
Service Stations (Including Refuelling of Cars)*

NOSE CODE:

NFR CODE: 1 B 2 a v

1 ACTIVITIES INCLUDED

050501	Refinery dispatch station
050502	Transport and depots (except 050503)
050503	Service stations (including refuelling of cars)

Refinery dispatch station category includes emissions from filling of transport equipment (e.g. tank trucks) taking place within the refinery area. Transport and depots category includes emissions from transport equipment and from storage tanks outside refinery. Additionally emissions from Border Terminal Dispatch Stations should be considered under this SNAP code since in some countries the gasoline is not only produced in the respective country but also imported by pipelines, ships, barges and road tankers (Schürmann, 1994). Service stations category includes emissions from tanks at the station (e.g. during filling, withdrawal) and emissions while refuelling cars. For more details see section 3.4.

2 CONTRIBUTION TO TOTAL EMISSIONS

Table 2.1 shows the contribution of the gasoline distribution sector to total man-made NMVOC emissions reported in the CORINAIR'90 emission inventory. On average this sector (0505) contributes about 3.5%, of which about 2/3 are emissions from service stations. The contribution in different countries varies from less than 2%, e.g. in Bulgaria and Poland to as much as 7% in Slovenia. Table 2.2 shows the contribution of this sector to total emissions in different countries in Europe as presented in various emission inventories.

Table 2.1: Contribution to total man-made NMVOC emissions in Europe reported in CORINAIR'90 emission inventory.

Source-activity	SNAP-code	Contribution (excluding emissions from nature) [%]							
		SO ₂	NO _x	NMVOC	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Refinery Dispatch Station	050501	-	-	0.2	-	-	-	-	-
Transport and Depots	050502	-	-	0.9	-	-	-	-	-
Service Stations	050503	-	-	2.3	-	-	-	-	-

0 - emissions are reported, but the exact value is below the rounding limit of 0.1 percent

- - no emissions are reported

Table 2.2: Contribution of gasoline distribution sector to total man-made NMVOC emissions

Country/Region	Year	Reference	Contribution to total man-made NMVOC emissions [%]			
			050500	050501	050502	050503
OECD Europe	1980	OECD, 1990	4.4			
OECD Europe	1983	Edwards et.al,1986	5.2			3.6
EC	1985	Bouscaren, 1990	4.4			3.2
Ireland	1985	Bouscaren, 1990	4.2			3.7
Netherlands	1985	KWS2000, 1989	5.0			2.3
Slovenia	1988	Rode, 1993	6.7			
UK	1988	Passant, 1993	4.3			
UK	1990	CORINAIR'90	5.1		1.9	3.3
Slovakia	1990	Mareckova, 1994	3.9		0.5	3.4
Bulgaria	1990	CORINAIR'90	1.8		0.4	1.4
Ireland	1990	McGettigan, 1993	1.8		0.4	1.4
Poland	1990	Fudala, 1993a	1.5			
Poland	1992	Fudala, 1993b	2.5			

Nearly all of 28 countries participating in CORINAIR'90 inventory reported emissions from this sector including 10 countries reporting emissions from the sector 050501, 21 from 050502, and 24 from 050503.

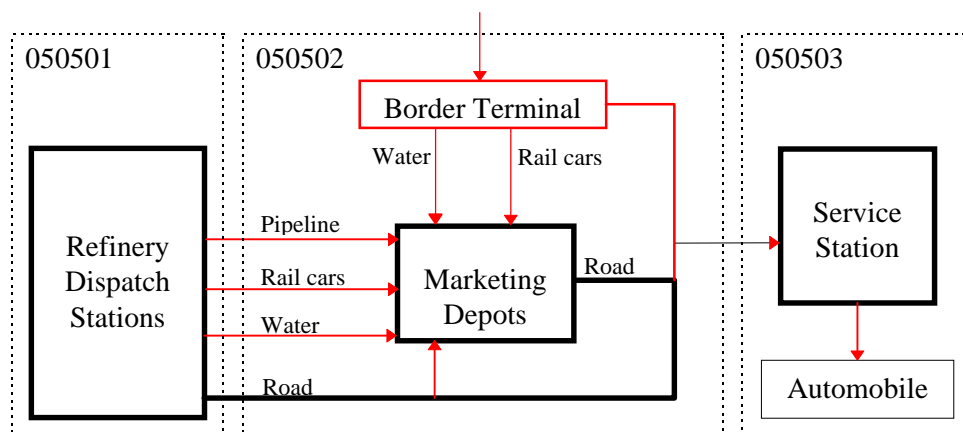
3 GENERAL

3.1 Description

Gasoline distribution starts at the refinery dispatch station (050501) or at the border terminal dispatch station (050502) from where it is loaded into rail cars, barges, coastal tankers, pipelines for delivery to marketing depots (050502) or into road vehicles for delivery to service stations (050503) or small marketing depots (050502). From marketing depots (or

directly from border terminals), gasoline is loaded into road vehicles for delivery to service stations where it is transferred into underground storage tanks and subsequently dispensed into automobile fuel tanks. This gasoline distribution chain is presented in Figure 3.1.

Figure 3.1: The gasoline distribution system (0505)



3.2 Definitions

Fixed Roof Tank

A fixed roof tank consists of a cylindrical steel shell topped by a coned roof and could be equipped with internal floating cover in aluminium or steel as well as with a pressure/Vacuum vent (PV vent).

Floating Roof Tank

A tank normally used in terminal operations which is equipped with a roof floating on top of the gasoline.

Marketing Depot

One or more storage tanks where gasoline is received by pipeline, road truck, barge or rail car, and is stored in bulk for subsequent transportation or distribution by road truck.

Onboard Canister

A container filled with an adsorbent (e.g., activated carbon) which collects gasoline vapours in a motor vehicle.

Reid Vapour Pressure (RVP)

The vapour pressure of a product (e.g. gasoline) is determined by a standard laboratory method called RVP, which measures its inherent tendency to evaporate at 38 °C with vapour/liquid ratio of 4/1. RVP is reported in kPa. For details of the equipment and procedures refer to the following standard methods: IP 69/78 (Vapour pressure Reid method), ASTM D323 (Vapour pressure of petroleum products Reid method), ISO 3000-1974 (Petroleum products - Determination of vapour pressure - Reid method).

Service Station

Any premises at which gasoline is dispensed into the fuel tanks of motor vehicles, including marinas (gasoline fuelling point which services water craft) with land-based storage.

Stage I Controls

The equipment used to recover gasoline vapours at terminals (dispatch stations), marketing depots, and from service stations.

Stage II Controls

The equipment used to recover gasoline vapours emitted during motor vehicle refuelling at service stations.

True Vapour Pressure (TVP)

If any liquid is introduced into an evacuated container, molecules will escape from the liquid surface by virtue of their kinetic energy to form vapour. Thereafter, some vapour will condense and eventually a state of equilibrium is reached, which is sustained if the temperature remains constant. The observed pressure in absolute units in the vapour space is defined as the true vapour pressure (TVP) of the liquid at the constant temperature applicable.

Vapour Balancing

Vapours displaced from tanks receiving gasoline are returned to tanks delivering the gasoline.

Vapour Destruction Unit (VDU)

An installation, normally located at a terminal, which receives gasoline vapours from cargo tank trucks and destroys them by thermal oxidation or other means.

Vapour Recovery Unit (VRU)

An installation, normally located at a terminal, which receives gasoline vapours from cargo tanks and recovers them for subsequent use, e.g. condensation.

3.3 Techniques

The refinery products (e.g. gasoline) are stored in tanks of different construction, i.e., fixed or floating roof tanks. Then the products are transferred to tank trucks, rail cars, etc., using various techniques of loading, i.e. top, bottom, or submerged loading. The gasoline is delivered directly to service station (stored in underground tanks) or to marketing depots where it is stored in tanks similar to those used in refineries. In some countries the products are imported and stored at border terminals before distribution (see Fig. 3.1).

Fixed Roof Tank

These tanks are normally equipped with a Pressure/Vacuum vent (PV vent) and can be vapour balanced. They continue to be used for motor gasoline at the smaller installations and depots, typified by lower throughput levels (Williams et al, 1986; ECE, 1990; CCME, 1991). These tanks could be classified as follows (Schürmann, 1994):

- Fixed roof tanks without internal floating roof and without pressure/vacuum (PV) vent;
- Fixed roof tanks with internal floating roof and without PV vent;
- Fixed roof tanks without internal floating roof and with PV valve, whereby pressure range (e.g. +20mbar/-5mbar or +180mbar/-50mbar) has an influence on storage emissions.

The internal floating roofs are typically made of steel or aluminium sheets. The steel internal covers are longitudinally welded and in direct contact with the liquid surface. The aluminium covers generally have a closed surface of clamped sheets and float several centimetres above the product surface on floats (VDI, 1985).

Floating Roof Tank

A tank normally used in terminal operations as well as at principal marketing installations away from refineries. It consists of a cylindrical steel wall equipped with a floating roof. The roof floats on top of the gasoline, and is equipped with seals to the sidewall to minimise vapour loss; the air space above a floating roof is vented to the atmosphere. Floating roof decks are of three general types: pontoons, pan, and double deck. A floating roof tank normally cannot be vapour balanced (Williams et al, 1986; ECE, 1990; CCME, 1991).

Bottom loading

A system for loading liquid petroleum products into a cargo tank truck from the bottom, through a system of pipes, valves and dry-disconnect fittings (CCME, 1991; Williams et al, 1986).

Splash Loading

The loading arm is positioned with the outlet above the tank bottom so that the gasoline falls to the liquid surface. This leads to a high vapour evolution (Williams et al, 1986; ECE, 1990).

Submerged Top Loading

A system for loading liquid petroleum products into any tank by means of a pipe to provide entry below the liquid surface, thereby minimising splash and vapour formation (CCME, 1991; Williams et al, 1986).

Underground Storage Tank

A storage tank that is completely buried by or covered with earth, backfill or concrete, or a partially buried tank. A partially buried tank means a storage tank that has 10% or more of its volume below adjacent ground level. These tanks normally have fixed fill pipes which discharge at the bottom of the tank (CCME, 1991; Williams et al, 1986).

3.4 Emissions

Emissions of hydrocarbons to atmosphere occur in nearly every element of the gasoline distribution chain. The emissions can be classified as follows (for details see Williams et al, 1986 and ECE, 1990):

1. Emissions from bulk storage tanks (refinery dispatch station, border terminals, marketing depots),
2. Service station storage tank emissions;

3. Transport vehicle filling emissions;
4. Other emissions.

3.4.1 Emissions from bulk storage tanks

There are basically two types of bulk storage tanks:

Floating Roof Tanks and Fixed Roof Tanks with internal floating covers

There are two major sources of emissions associated with the storage of intermediate volatility liquids:

- a) *Standing storage emissions* are caused mainly by evaporation of liquid product through imperfections in the flexible peripheral seals. Included are any evaporative emissions through the deck structure and fittings such as manholes, gauge pipes and hatches, also roof support columns or legs. The emissions vary depending on design of surface covers (steel or aluminium), see section 3.3. Techniques and 3.5. Controls. Additionally the wind can have a significant influence on the magnitude of these emissions if the tanks are ventilated.
- b) *Withdrawal emissions* occur following the withdrawal of liquid product. They are due to evaporation of the film of gasoline which adheres to the surface of the tank walls, and any tank roof support columns fitted. The magnitude of these emissions is mainly influenced by the surface condition e.g., presence of rust or a tank lining.
- c) *Filling of the tank* after revisions or complete emptying when the floating roof stands on its supports causes additional emissions.

Fixed Roof Tanks without internal floating covers

- a) *Displacement emissions* occur due to displacement of the mixture of air and hydrocarbon vapour by the incoming gasoline. The vapour emitted originates mainly by evaporation from the previous tank contents during storage.
- b) *Withdrawal emissions* occur following intake of air via the pressure/vacuum relief valves. Dilution of the hydrocarbon vapour/air mixture previously contained in the vapour space will lead to further evaporation to restore the equilibrium.
- c) *Working emissions* are defined as the sum of displacement and withdrawal emissions caused by gasoline movements.
- d) *Breathing emissions* are caused by temperature variations and changes in the barometric pressure which in turn cause expansion and contraction of both liquid and vapour within the tank.

3.4.2 Service station storage tank emissions

The main contribution comes from displacement when an incoming bulk delivery of gasoline is received into tanks. There are also withdrawal and breathing emissions, the latter being of minor significance since tanks are normally double walled underground tanks and are not subject to "above-ground" diurnal temperature changes but the variation in atmospheric pressure influences the breathing emissions.

See also note in section 14. Additional Comments on emissions from leaking underground storage tanks.

3.4.3 Transport vehicle filling emissions

These occur when gasoline is transferred from storage tanks into transport vehicles, i.e. road tankers, rail cars, barges, and when dispensed into cars. The emissions are a combination of vapour from the previous tank contents and the vapour evolved as a result of splashing and turbulence during filling. The transit or breathing losses are minor (see section 3.4.4.d). It might be worth paying more attention to vapour emissions resulting from spillage when refuelling cars. Four categories of loss were identified (see below). Most of these losses can be avoided by correct maintenance and handling of the dispensing equipment.

- a) Pre-fill drip from the nozzle while being handled between the pump and the vehicle,
- b) Spit-back of gasoline from the fuel tank filler pipe, resulting from the pressure build-up in the vapour space,
- c) Overflow from the filler pipe,
- d) Post-fill drip from the nozzle while being handled between the vehicle and the pump.

3.4.4 Other emissions

Emissions described here are of minor magnitude as compared to those described above and include the following:

- a) *Fugitive emissions* occur following seepage of gasoline liquid through parts of handling equipment such as pipeline gaskets, also pump and valve stem seals. Pipelines are closed systems and essentially emission free. They are however subject to some fugitive losses and possible leaks due to temperature rise.
- b) *Ship and barge ballasting emissions* - hydrocarbon vapours are displaced into the atmosphere when a compartment, which has previously contained gasoline, is loaded with ballast water.
- c) *Transport vehicle emissions whilst travelling* are often negligible because the vapour and pressure retention capability of the tank or compartment will be above the level at which breathing will be induced by the temperature variations that may occur. However, in some cases these emissions should not be neglected; the containers of road vehicles are subject to significant heating up (depending on colour also) whilst the pressure range of their PV vents is limited to 50 mbar, corresponding to a temperature difference of +15°C, ignoring expansion of liquid. Many rail cars are free vented and their emissions are not negligible.
- d) *Spillage and leakage* - any activity involving the transfer of gasoline from one form of container to another is a potential point of spillage. Also, leakage from storage and handling equipment such as loading arms, swivels and storage tanks, in addition to flanges and valves, can contribute to vapour emissions. Such emissions should only make a minimum contribution to the total which occur in the gasoline distribution sector, providing facilities are well designed and operated efficiently.

3.5 Controls

Considerable reduction of hydrocarbon emissions from gasoline distribution network is achieved by modifying truck, barge or rail car tanks loading practices, installing closed vapour recovery units (VRU), as well as providing fixed roof storage tanks with internal floating covers. Additionally, Stage I and Stage II control measures are being introduced. For more details on control options described in this section see Richards et al, 1990; ECE, 1990; Williams et al, 1986; CCME, 1991; VDI, 1985; EPA, 1985.

3.5.1 Storage Tanks

There are several ways to control emissions from storage tanks. In most major terminals, vapour emissions from working tankage are controlled by the use of floating roof tanks or fixed roof tanks with internal floating covers (IFCs). These will reduce vapour emissions from tankage by at least 90% for welded steel pans (VDI, 1985). If aluminium pans are used the reduction efficiency may be lower (ca. 70%). A very simple but effective measure is to paint the shell of tank white. A white coating reflects 70% of the energy of the irradiating sunlight (see VDI, 1985 for more details on effects of different colour and type of coatings). Another option is to install Stage IA devices, described in section 3.5.2. There is an extensive experience in use of internal floating covers and replacement of fixed roof tanks by floating roof tanks. In Finland and Germany the majority of fixed roof tanks are equipped with IFCs. In Canada, in 1983, 89% of this category of tanks were equipped with floating roof (Made, 1988).

Important note:

It is believed that because of the change to unleaded gasoline, the rubber elements, like seals, are deteriorating faster. Therefore, the given reduction efficiencies for storage tanks might not be achieved in some cases (M. Wyser, J. Baumann; pers. communication).

3.5.2 Stage I Controls

Stage I controls refer to a variety of techniques reducing VOC emissions at marketing terminals (Stage IA) and when gasoline is delivered to service stations (Stage IB).

Stage IA

Stage IA systems basically include two parts:

- a) *Vapour Balance Lines between Tanks and Loading Gantries* - When a group of fixed-roof gasoline tanks is subject to simultaneous receipts and deliveries, interconnecting the tank vapour spaces can reduce emissions to atmosphere by allowing displaced vapours from a receiving tank to flow into the vapour space of a delivering tank. In some areas vapour return lines have been installed to reduce exposure of vehicle loading personnel to gasoline vapours. Currently, these lines are generally installed in conjunction with a vapour recovery unit (VRU). In Switzerland, all of the marketing depots are fully equipped with vapour balance lines between road tankers and tanks as well as between tanks and tank cars.
- b) *Vapour Recovery Units (VRU)* remove hydrocarbons emitted from tanks or vehicle loading operations usually by either cooling/condensation, liquid loading absorption or carbon

adsorption or a combination of these processes (for details of the processes see ECE, 1990). The recovered hydrocarbons are usually returned to tankage in liquid form. VRUs are either single-stage, based on one of the above mentioned processes, with recovery efficiencies of the order of 95%, or double-stage, with additional processing of the first stage tail gas, with design efficiencies close to 100%. Until 1988, relatively small number of VRUs had been installed in Europe (Richards et al, 1990) of which the large majority are for road vehicle loading. Recently installed units are designed to meet the US EPA limits of VOC emissions per litre of product loaded into a vehicle, i.e. 35g/m³ requires single-stage unit, or more stringent TA-Luft limits, i.e. 150 mg/m³ requiring double-stage VRUs. In Switzerland, VRUs are installed at border terminals and refineries.

Richards et. al, 1990 gives average efficiencies of Stage IA systems, assuming 95% efficiency of VRU, 95% vapour collection efficiency at the loading gantry for bottom loading and 85% for top loading, as 90% and 80%, respectively. These numbers are based on an average TVP of 35 kPa. Schürmann, 1994 uses different efficiencies, namely 100% for bottom loading and 85% for top loading with gas balancing systems.

Stage IB

Stage IB applies to vapour balancing systems between service station tanks and trucks supplying gasoline to them. Saturated vapours, displaced from the tank vent pipes when receiving gasoline, are returned to the truck compartment from which the gasoline is supplied, via a piping system and/or hoses. There are several piping configurations possible, for details see Richards et. al, 1990, ECE, 1990, Williams et al, 1986. According to CONCAWE (Richards et. al, 1990) about 33% of service stations in EC12 countries in 1988 were equipped with Stage IB systems. It has been reported that with well designed systems vapour collection efficiencies are higher than 95%. Schürmann, 1994 uses in his report a reduction efficiency of 100% for stations equipped with Stage IB controls.

3.5.3 Tank Trucks

To reduce emissions, modified loading techniques are recommend, namely:

- a) Submerged top loading (reduces VOC emissions by 40 to 60%),
- b) Submerged top loading with in-line vapour return,
- c) Submerged top loading with external vapour return,
- d) Bottom loading,
- e) Bottom loading with vapour return .

Vapour collection and return from service stations is only undertaken in five European countries and both top and bottom loading trucks are equipped there with vapour return systems. In the USA, bottom loading with vapour return has been legally enforced by EPA standards since 1982. A typical emission reduction efficiency for vapour recovery at tank truck loading points given by OECD, EEC and CONCAWE is 89%. But there are several units installed in Germany to meet stringent regulations and their efficiency is 99.9% (ECE, 1990). This is also reported for Switzerland (Schürmann, 1994; M.Wyser pers. comm.).

3.5.4 Rail Cars

Rail cars are generally top loaded in Europe. The recommended techniques to reduce emissions are the same as for tank trucks (see 3.5.3). According to OECD, EEC, and CONCAWE, vapour recovery units are operating with an average efficiency of 89% at rail car loading points (ECE, 1990). Schürmann, 1994 reports 85% efficiency for top loading operations with gas balancing systems. This efficiency could be improved if bottom loading would be introduced on a wider scale. Its introduction would additionally require automatic overfill protection systems on all rail cars.

3.5.5 Barges/Ships

Modified loading techniques reduce loading losses by 60 to 80%. This involves low initial loading to reduce turbulence when filling the bottom, fast bulk (bottom) loading and slow final loading to reduce turbulence in the vicinity of the ullage as the liquid approaches the top (ECE, 1990). Vapour return/recovery systems are not very common. For inland barges equipped with such systems efficiencies of 88% and for ocean ships of 89% are reported by the EEC (Bouscaren et. al, 1988). Sometimes, the controls are installed but not used, according to M. Wyser (pers. communication) inland tankers on the Rhine river are equipped with vapour balancing systems but the systems are not used.

3.5.6 Car Refuelling

Stage II Controls

Stage II applies to vapour balancing systems between automobile fuel tanks during refuelling and the service station tank supplying the gasoline. Saturated vapours are displaced from the automobile fuel tank and returned to the service station tank via special fittings in the dispensing nozzle. Vapour escape from the automobile fill-pipe to the atmosphere is prevented by a special bellows which seals the fill pipe and routes the displaced vapours through the body of the dispensing nozzle to the hose. Different systems are available, in some of which the vapour flow is boosted by a vacuum pump. Essential to this system are standardised fill pipes and existence of Stage IB controls in place, otherwise Stage II devices may only delay the venting of vapour to the atmosphere.

In the late 80's, comprehensive test programmes were carried out in Sweden and Switzerland to estimate the recovery efficiency applying Stage II controls. The recovery efficiency of the system, weighted to the Swedish car population, was determined to be 56% and for Switzerland 53% (Switzerland has decided in 1989 to introduce Stage I and II controls at all service stations and vapour recovery at the principal storage units by 1994). Similar results were achieved in an investigation of the BP oil company at one of its stations in Stockholm. The recovery efficiency varied from 11 to 89%, average 61%, depending on the car type. To achieve a better efficiency, it will be necessary to introduce modifications to all new European car fill-pipes and tank vents. In the absence of these changes, an average efficiency between 50 and 60% can be assumed (Richards et. al, 1990). In the USA, where standardisation has been introduced, the EPA estimates the average in-service efficiencies at 62 to 86%, depending on the level of regulatory enforcement, mainly regular inspection. Additional problems with Stage II equipment, mentioned in the literature, are that this system

cannot be used with shallow fuel tanks (motorcycles) and that American experience indicates greater spillage when these systems are installed.

On-board Canisters

These are a viable alternative to Stage II controls. According to the experience in the USA and CONCAWE (McArragher et al, 1988), enlarged carbon canisters could reduce refuelling emissions by more than 95%. Canisters are filled with activated carbon to which all external fuel system vents are connected. Any diurnal, hot soak as well as refuelling hydrocarbon emissions are adsorbed by the carbon and retained in the canister. The carbon is purged of hydrocarbons during normal driving by drawing the air back through the canister and into the engine where it is burnt.

RVP Reduction

This control option requires the reduction of gasoline volatility at the refinery from May to September. A reduction of volatility (RVP) of 17 kPa (from 79 to 62 kPa) would result in a 8 to 10% reduction of the annual emissions of VOC from the gasoline distribution sector (Environment Canada, 1989). Gasoline volatility reduction is reported to reduce VOC emissions from refuelling by 23% (ECE, 1990).

4 SIMPLER METHODOLOGY

The simpler methodology is based on aggregated average emission factors (see section 8.1) combined with information on pumped volume of gasoline in the country. Where the information on type, efficiency and extent of emission control measures applied in distinguished sectors is available, the detailed methodology should be used.

Emission = (Average emission factor, see Table 8.1) x (pumped volume of gasoline)

This simpler approach has been applied by CONCAWE to estimate emissions of VOC from the gasoline distribution sector in Western Europe (Edwards et. al, 1986). Similar average emission factors for the elements of gasoline distribution system are also given (with some reservations - see Veldt et. al, 1992) in the Second Edition of the CORINAIR Inventory Default Emission Factors Handbook (Bouscaren, 1992).

5 DETAILED METHODOLOGY

To improve the quality of emission estimates, country specific data should be taken into account. Therefore, the detailed methodology requires knowledge on specific parameters of the gasoline distribution system (see section 6 below). Additionally basic physical and chemical parameters of distributed gasoline should be known. For details see procedure described in reference studies i.e., Williams et al, 1986; Foster et al, 1987; VDI, 1985.

An alternative methodology was offered by Swiss BUWAL (Bundesamt für Umwelt, Wald und Landschaft) (Schürmann, 1994). The following paragraph gives a general description of the methodology and is quoted after Schürmann, 1994.

The proposed detailed methodology is based on the analysis of gasoline flows from imports and refineries to car filling stations and the various loading and unloading techniques used. From the gasoline flow, a gas flow model is derived, which is analysed with regard to gas handling techniques to give distribution emissions on one hand and on determination of storage emissions on the other hand. It involves the following steps:

- a) Determination of the gasoline flows (in Mg/a) from the product sources (refineries and imports) to the filling stations.
- b) Determination of the gas flows (in m³/a) from the gas source (car) to the various emission locations or emission control locations
- c) Determination of the VOC-emissions for gasoline distribution (in kg/a)
- d) Determination of the VOC-emissions for gasoline storage (in kg/a)

This methodology has the following advantages:

- It reflects the actual emission situation better than aggregated emission factors,
- The results reflect directly the percentage of introduction of gas handling control measures (e.g. stage I and stage II) and of VRU installations in terminals,
- The emission factors for the various emission sources can be adapted to the local properties of gasoline composition, to the level of introduction of integral gas balancing techniques etc.,
- The detailed methodology is a model calculation which allows an analysis of the efficiency of various control measures and as such is an instrument for the planning of the introduction of control techniques.

The current version of this methodology is being reviewed, extended and tested by Swiss BUWAL. An up-to-date version, description and the diskette may be ordered from Dr. Jürg Baumann, BUWAL, Laupenstr. 20, 3003 Bern, Switzerland.

The following sections in this chapter of the guidebook do not refer to the 'Swiss' methodology since it was not available at the time of writing.

6 RELEVANT ACTIVITY STATISTICS

6.1 Simpler methodology

To estimate VOC emissions from the gasoline distribution sector (0505) the statistics of gasoline sold in the country/region are required. For calculation of emissions resulting from activities in relevant subsectors of gasoline distribution, distinguished in CORINAIR, emission factors given in section 8.1 of this document are used.

To take into account emission control measures in place, necessary data may be available from sectoral statistics or country studies. The reduction efficiencies given in section 3.5 of this document could be applied or (preferably) the efficiencies reported in national studies

should be used. However, it is considered that where information on controls is available the detailed methodology described below or the 'Swiss' method should be used.

6.2 Detailed methodology

More detailed country specific data are needed as far as the technical parameters of equipment as well as operation practices are concerned. This includes:

- a) *Refinery Dispatch Station (050501)* - number, type, size of the tanks used at the refinery dispatch station as well as volume of gasoline stored in these tanks; volume of gasoline loaded into different transport modes (e.g., rail truck, pipeline, tank truck); gasoline loading practices for specific modes of transport (e.g., top-submerged, bottom); type and extent of emission control measures in place (e.g., Stage I).
- b) *Transport and Depots (050502) and Border Terminal, where applicable* - number, type, size of the tanks used as well as volume of gasoline stored in these tanks; gasoline loading practices for used transport modes; type and extent of emission control measures in place (e.g., Stage I).
- c) *Service Stations (050503)* - volume of gasoline sold; type and extent of emission control measures in place (e.g., Stage II , percentage of cars equipped with enlarged carbon canisters, the latter not relevant for past year inventories as this technology is not yet in use).
- d) *Characteristics of distributed gasoline* - RVP, TVP, density.

Additionally, some meteorological data like average annual (or seasonal) temperature are needed to improve the quality of the inventory or calculate the seasonal variation in emissions.

7 POINT SOURCE CRITERIA

Not applicable - see section 12.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

The emission factors presented are derived from the study of CONCAWE (Williams et al, 1986). The assumed liquid gasoline density is 730 kg/m^3 and condensed vapour density is 600 kg/m^3 . Hydrocarbon emission factors for uncontrolled techniques are given in Table 8.1.

Table 8.1: NMVOC emission factors [g NMVOC/Mg of total gasoline handled]

Category	Emission factor	Quality code
Refinery Dispatch Station (050501)	310	D
Transport and Depots (050502)	740	D
Service Station (050503)	2880	D
Gasoline Distribution (0505)	3930	D

Information provided in CORINAIR'90 database suggests that many experts used very similar average emission factors for considered sectors. Average emission factors used for 050501 vary from 200 to 500 g/Mg, for 050502 from about 600 to as much as 3120 g/Mg (in Germany), and for 050503 from 2000 to 4500 g/Mg. The information on gasoline and vapour density is not provided in CORINAIR database. The values provided in the Table 8.1 are also confirmed by Czech estimates provided by Mr. B. Bretschneider (pers. comm.), based on the Czech emission inventory system REZZO. The emission factors estimated at different gasoline terminals (050502) vary from about 300 to nearly 1500 g/Mg with an average of 800 g/Mg of gasoline. For the service stations REZZO suggests emission factors from about 1500 to 2500 g/Mg with an average 1660 g/Mg of gasoline, it is not clear though if the emissions from loading of the tanks at the service stations are included in this estimate, i.e. it might represent emissions from car refuelling and spillage only.

8.2 Detailed Methodology

The emission factors given in this section are derived from the CONCAWE studies (see Williams et al, 1986; Foster et al, 1987) assuming the following typical European gasoline properties:

true vapour pressure (TVP)	35 kPa
liquid molecular weight	64 kg/kmol
condensed vapour density	600 kg/m ³
liquid gasoline density	730 kg/m ³

Additionally, emission factors reported in the ECE, 1990 study are given in brackets. They are, in general, based on experience of the United States Environment Protection Agency (US EPA).

8.2.1 Refinery Dispatch Station (050501)

It is assumed that there are only external floating roof (EFR) tanks in use at the refineries. They are equipped with mechanical shoe primary seal (see section 3.3.3.1. in Williams et al, 1986). Storage tank emissions are the sum of standing storage and withdrawal emissions.

The emission factors for ship/barge loading operations are weighted averages of conditions specified in the CONCAWE report (Williams et al, 1986). Where detailed data on the prior cargo and compartment treatment for the previous empty or ballasted voyage are available, emission factors specified in section 3.3.4.5 in Williams et al., 1986 should be used. In brackets emission factors reported in ECE, 1990 are given.

One of the parameters, used to evaluate emission factors for rail/truck tank loading operation, represents the amount of splashing. Its value depends on loading practice as well as the arm outlet height from the bottom of compartment. Some typical values estimated by BP, 1973 were used. Where detailed data exist, the values and the formulas given in section 3.3.4.3 and 3.3.4.4. in Williams et al, 1986 should be used.

Table 8.2: NMVOC emission factors (uncontrolled) for Refinery Dispatch Station (050501) [g NMVOC / Mg gasoline throughput]

Category	Emission factor ^{1) 2)}	Quality code
Storage tank emissions (EFR)	26	D
Loading		
Pipeline	0	C
Ship/ocean barge	300 (430)	C
Shallow draft barge	560 (640)	C
Rail cars		
Top-submerged	500 (800)	C
Top-partial splashing	1060 (2000)	D
Road trucks:		
Splash loading	(2050)	E
Top - partial splashing	870	D
Top - submerged	450 (670)	C
Bottom	410 (670)	C

¹⁾ reported emission factors are based on Williams et al., 1986

²⁾ emission factors in brackets are based on ECE, 1990.

8.2.2 Transport and Depots and Border Terminals (050502)

The breathing emissions during transport of gasoline from the refinery to the marketing depots or service stations are not significant, they are assumed to be less than 0.001% liquid volume (see Williams et al, 1986). Ballasting emissions depend on intake of ballast water after a gasoline cargo discharge. In table 8.3, intake of water is expressed as percent volume of gasoline discharged. In the study by ECE, 1990 an average emission factor, based on US EPA experience, is given in brackets. For external floating roof (EFR) and internal floating cover (IFC) tanks, storage emissions are the sum of standing storage and withdrawal emissions. Fixed roof tanks storage emissions are the sum of working and breathing emissions (see section 3.4 of this document).

Where Border Terminals are equipped with storage tanks comparable to the tanks in the refinery and other modes of transport than road trucks are used, coefficients from table 8.2 should be applied accordingly.

Table 8.3: NMVOC emission factors (uncontrolled) for gasoline - Transport and Depots [g NMVOC/ Mg gasoline throughput]

Category	Emission factor ¹⁾²⁾	Quality code
Transport from refinery	< 8	C
Ballasting (ships/barges)		
water intake - 100%	220	C
water intake - 30%	66	C
ECE, 1990	140	D
Storage tank emissions		
EFR - primary seal	73	D
EFR - secondary seal	5	D
IFC	160	D
Fixed roof	1570	E
Loading - road trucks		
Splash Loading	(2050)	E
Top - partial splashing	870	D
Top - submerged	450 (670)	C
Bottom	410 (670)	C
Other		
Fugitive	< 8	C
Spillage	80	C
Transport to service stations	< 8	C

¹⁾ reported emission factors are based on Williams et al., 1986

²⁾ emission factors in brackets are based on ECE, 1990.

8.2.3 Service Stations (including refuelling of cars) (050503)

Emission factors reported here are derived from CONCAWE study (Williams et al, 1986) and from the report by ECE, 1990 (given in brackets).

**Table 8.4: NMVOC emission factors (uncontrolled) for Service Stations (050503)
[g NMVOC / Mg gasoline throughput]**

Category	Emission factor ¹⁾²⁾	Quality code
Filling/Storage		
Submerged loading	1315 (1400)	C
Splash loading	(2050)	C
Car filling	1480 (1800)	C
Spillage	80 (110)	C

¹⁾ reported emission factors are based on Williams et al., 1986

²⁾ emission factors in brackets are based on ECE, 1990.

9 SPECIES PROFILES

Measurements of hydrocarbon composition in the gasoline distribution system are fairly consistent, reflecting the fact that one deals with a single product of relatively constant composition. Thus, measurements taken at tank vents, and downwind from the terminal in unrelated locations give generally the same results. Limited data on emissions from service stations are consistent with the known composition of emissions from terminals handling gasoline (Edwards, et. al, 1986). These data are presented in Table 9.1. The last column in this table shows composition of gasoline vapours from petroleum industry (adapted from Veldt et. al, 1992). The data are averages derived from literature review of measurement experience in many countries (to large extent US - for details see EPA, 1990). According to Veldt et. al, 1992, the composition of gasoline vapour is highly variable depending on liquid composition (e.g., summer and winter blend) as well as on the evaporation process (temperature and time). However, aggregating species to groups as in Table 9.1 shows quite a good agreement of composition derived from both studies.

10 UNCERTAINTY ESTIMATES

In this chapter, the methodology to calculate the emissions from gasoline distribution system as well as from storage of gasoline in the refinery dispatch station is described. However, chapter 040104 'Storage and Handling of Petroleum Products in a Refinery' in this guidebook covers the latter source. Therefore, there is a danger of double counting especially in case when the simplified methodology is used and consequently aggregated emission factors are used. There is a need to discuss this issue and possibly modify the SNAP code, i.e. exclude, for example, emissions from refinery dispatch station from this subsection or replace it by border terminal stations (where applicable) and then the gasoline distribution system would only include gasoline flow outside the refinery.

Table 9.1: VOC profiles of gasoline terminal air samples (Edwards et. al, 1986) and of petroleum industry emissions of gasoline vapour (Veldt et. al, 1992) [wt. %]

Substance	Tank vent	Downwind	Petroleum ind.
<i>Alkanes</i>			
Ethane	-	-	-
Propane	-	2.0	1.0 (0.2 - 2)
C ₄ +	89.2	89.1	85.0 (>45)
<i>Alkenes</i>			
Ethene	-	-	-
C ₃ +	6.9	6.5	11.0 (>5.5)
<i>Aromatics</i>			
Benzene	1.1	1.5	1.0 (0.5 - 2)
Toluene	2.0	0.9	1.5 (0.5 - 3)
Xylene	0.8	-	0.5 (0.1 - 1)
TOTAL	100.0	100.0	100.0

11 WEAKEST ASPECTS / PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The methodology presented in this chapter is based on hypothetical, representative for Western Europe distribution network but it may not reflect real situation (system configuration) in a particular region or country (compare remarks in section 8 on emission factors used in CORINAIR inventory). Therefore, measurement campaigns carried out by independent groups of experts as well as comparison of emission factors with other countries could provide a valuable input to the continuous improvement of emission estimation technique.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Where no detailed information is available on location and throughputs of considered elements of the gasoline distribution network, the emissions from service stations (050503) should be distributed evenly across regions (e.g., administrative units) or grids or based on population data. The same applies to emissions from sub-sector (050502) if the appropriate data are not available although the location and throughput of principal marketing depots as well as border terminals should be known. The location of refineries is usually known (in many countries there are few, if not only one). Therefore, emissions from refinery dispatch stations (050501) can be attributed to a particular region or grid.

13 TEMPORAL DISAGGREGATION CRITERIA

The true vapour pressure (TVP) of gasoline is influenced by its temperature and Reid vapour pressure (RVP). It is possible, using equations given in Williams et al, 1986, to calculate emissions, resulting from storage and loading operations, from gasoline distribution sector, including data on gasoline properties (e.g., RVP) and average annual or monthly temperature.

An experimental work carried out by Deutsche Gesellschaft für Mineralölwissenschaft und Kohlechemie (DGMK, 1976) showed a seasonal variation, in filling/storage emissions from service stations, of 0.145/0.125% mass which occurred in summer/winter, respectively.

14 ADDITIONAL COMMENTS

Recently, US EPA has contracted Radian Corporation to develop the methodology to estimate VOC emissions from leaking underground storage tanks (LUST) (R.Ryan, US EPA, pers. communication). LUST are typically not considered a quantifiable source of air emissions until excavation and remediation efforts are initiated. In many cases, the leaking tank and surrounding soil are removed and either placed in piles or evenly spread to allow volatilisation of the contaminant. It is a common practice, especially where the contaminant is highly volatile, like for example gasoline. This note is only to inform about such activity as the final results are not yet available. It is believed that this source of emissions might contribute to local ozone episodes.

To forecast the emissions of VOC from a gasoline distribution system the forecast of gasoline demand is necessary as well as the extent and type of control options introduced. There are usually several energy forecasts available but it is more difficult to find information on possible technical development as well as plans for introducing particular controls. In this case, the emission development scenario could be based on energy forecast and on known current and forthcoming emission regulations, and on current national or international agreements on emission reductions.

15 SUPPLEMENTARY DOCUMENTS

Williams, L. J., D. Beardshall, P. G. Edgington, F.O. Foster, R.H. Lilie, H.D. Richards (1986): Hydrocarbon Emissions from Gasoline Storage and Distribution Systems. Report No. 85/54, CONCAWE, Den Haag, September 1986.

16 VERIFICATION PROCEDURES

The emission factors presented in this chapter are not necessarily representative for a particular region/country due to substantial differences in handling practices, product properties as well as meteorological conditions. The verification can be based on local measurements or measurements performed for similar conditions.

17 REFERENCES

Bouscaren, R., N. Allemand, W. F. J. M. Engelhard, S. C. Wallin, K.-H. Zierock (1988): Volatile Organic Compounds and Nitrogen Oxides - Cost Effectiveness of Measures Designed to Reduce the Emissions of Precursors of Photochemical Oxidants, Phase 1 - Final Report. Commission of the European Communities, Report No. EUR 11856 EN, May 1988.

Bouscaren, R. (1990): Volatile Organic Compounds: EC - Emission Inventory (CORINAIR Project) in proceedings from "Workshop on Long-Range Transport of Organic Pollutants", Stockholm, Sweden, March 12-14, 1990. Report 3807, Swedish Environmental Protection Agency.

BP (British Petroleum Co) (1973): Emissions of gasoline vapour when loading transport media in Germany. Parts 1 and 2. Operations Services Branch Report No. 187, British Petroleum Co., July 1973 London.

CCME (Canadian Council of Ministers of the Environment) (1991): Environmental Code of Practice for Vapour Recovery in Gasoline Distribution Networks. Prepared by the National Task Force on Vapour Recovery in Gasoline Distribution Networks. CCME-EPC/TRE-30E, CCME, Canada.

DGMK (Deutsche Gesellschaft für Mineralölwissenschaft und Kohlechemie) (1976): Messung und Ermittlung von Kohlenwasserstoffen-Emissionen bei Lagerung, Umschlag und Transport von Ottokraftstoffen und Prüfen von Verfahren zur Beherrschung dieser Emissionen. Parts I, II and III. Report No. 4590. Hamburg, DGMK e.V.

ECE (Economic Commission for Europe) (1990): Emissions of Volatile Organic Compounds (VOC) from Stationary Sources and Possibilities of their Control - Final Report. ECE - VOC Task Force, Karlsruhe, July 1990.

Edwards, A. H. et. al (1986): Volatile Organic Compound Emissions: An Inventory for Western Europe. Report No. 2/86. Den Haag, CONCAWE

Environment Canada (1989): Development of a National Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOC) Management Plan for Canada. Technical Annex on: I - Environmental Objectives and Criteria; II - NO_x Emissions and Control Technologies; III - VOC Emissions and Control Technologies. Conservation and Protection, Environment Canada, July 1989

EPA (United States Environmental Protection Agency) (1985): Compilation of Air Pollutant Emission Factors, Vol. 1, 'Stationary Point and Area Sources'. EPA Report No AP-42, fourth edition.

EPA (United States Environmental Protection Agency) (1990): Air Emissions Species Manual. Volume I: Volatile Organic Compound Species Profiles - Second Edition. EPA-450/2-90-001a, January 1990

Foster, F. O., R. H. Lilie, W. G. Roberts, G. A. van Ophem (1987): Cost-Effectiveness of Hydrocarbon Emission Controls in Refineries from Crude Oil Receipt to Product Dispatch. Report No. 87/52, CONCAWE, Den Haag, January 1987.

Fudala, J. (1993a): Report on NMVOC Emission in Poland in EMEP Grid for the year 1990. Institute for Ecology of Industrial Areas, Katowice, December 1993.

- Fudala, J. (1993b): Report on NMVOC Emission in Poland for the year 1992. Institute for Ecology of Industrial Areas, Katowice, December 1993.
- KWS 2000 (Project Group Hydrocarbons 2000) (1989): Control Strategy for Emissions of Volatile Organic Compounds. Ministry of Housing, Physical Planning and Environment. The Netherlands, February 1989.
- Made, B. (1988): Control of VOC Emissions from Oil Refineries - Technologies Currently in Place in Canada. Environment Canada.
- Mareckova, K. (1994): CORINAIR 90 Emission Inventory for Slovakia - Final Report. Slovak Hydrometeorological Institute (SHMI), Department of Environmental Protection, Bratislava.
- McArragher, J. S. et. al (1987): An Investigation Into Evaporative Hydrocarbon Emissions from European Vehicles. Report No. 87/60, CONCAWE, The Hague.
- McGettigan, M. F. (1993): CORINAIR 1990 Emission Inventory for Ireland - Final Report. Environmental Research Unit, Department of the Environment. Dublin, July 1993.
- OECD (Organisation for Economic Co-operation and Development) (1990): Emission Inventory of Major Air Pollutants in OECD European Countries. Environment Monographs No. 21. OECD, Paris
- Passant, N. R. (1993): Emissions of Volatile Organic Compounds from Stationary Sources in the United Kingdom. LR 990, Warren Spring Laboratory, December 1993.
- Pazdan, W. et. al (1994): CORINAIR - Poland 1990 - Final Report. ATMOTERM, Opole.
- Richards, H. D. et. al (1990): VOC Emissions from Gasoline Distribution and Service Stations in Western Europe - Control Technology and Cost-effectiveness. Report No. 90/52. Brussels, CONCAWE
- Rode, B. (1993): VOC Emissions in Slovenia in 1988. in Baars, H.P. et. al [ed] Proceedings of the TNO/EURASAP Workshop on the Reliability of VOC Emission Data Bases, June 9-10, 1993. IMW-TNO Publication P 93/040. Delft, The Netherlands.
- Schürmann (1994): Study on the Detailed Methodology of the Determination of VOC-Emissions in Gasoline Distribution (DRAFT). Weyer Verfahrenstechnik, Basel, Switzerland. December 19, 1994. Study on request of Federal Office of Environment, Forests and Landscape, Section Air Pollution Control, Bern, Switzerland.
- VDI (Verein Deutscher Ingenieure) (1985): Emissionsminderung Raffinerieferne Mineralölvertriebsläger. VDI - Kommission Reinhaltung der Luft, VDI 3479. VDI-Verlag GmbH, Düsseldorf, Germany, July 1985.
- Veldt, C., A. Bakkum, R. Bouscaren (1992): Default Emission Factors from Stationary Sources (NO_x - VOC including CH₄) in R. Bouscaren: Default Emission Factors Handbook - Second Edition. CORINAIR Inventory, Commission of the European Communities. CITEPA, Paris, January 1992.
- Williams, L. J., D. Beardshall, P. G. Edgington, F.O. Foster, R.H. Lilie, H.D. Richards (1986): Hydrocarbon Emissions from Gasoline Storage and Distribution Systems. Report No. 85/54, CONCAWE, Den Haag, September 1986.

18 BIBLIOGRAPHY

Allemand, N., R. Bouscaren, D. Heslinga, I. Marlowe, C.J. Potter, M. Woodfield, K. H. Zierock (1990): Costed Evaluation of Options for the Reduction of Photochemical Oxidant Precursors, Volume 2. - Abatement Technology and Associated Costs. Report No. EUR 12537/II EN, Commission of the European Communities, Brussels - Luxembourg.

Bouscaren, R. (1992): Default Emission Factors Handbook - Second Edition. Corinair Inventory, Commission of the European Communities. CITEPA, Paris, January 1992.

CPPI (Canadian Petroleum Products Institute) and Environment Canada (1991): Atmospheric Emissions from Canadian Petroleum Refineries and the Associated Gasoline Distribution System for 1988. CPPI Report No. 91-7, February 1991.

CONCAWE (1990): Closing the Gasoline System - Control of Gasoline Emissions from the Distribution System and Vehicles. Report No. 3/90, CONCAWE, Brussels.

Thomas, Lee M. (1989): A US Perspective on Hydrocarbon Controls at Service Stations. Report No. 11/89, CONCAWE, The Hague.

19 RELEASE VERSION, DATE AND SOURCE

Version: 2.1

Date: 1 February 1999

Original and update
author: Zbigniew Klimont
IIASA
Austria

20 POINT OF ENQUIRY

Any comments on this chapter or enquiries should be directed to:

Zbigniew Klimont

IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

Tel: +43 2236 807 547
Fax: +43 2236 807 533
Email: klimont@iiasa.ac.at