Background

Gas distribution network operation is one of Gaz de France core business. Mains Gaz de France operates (and the corresponding services) were laid at different time periods with different techniques, from grey iron to HDPE. During the nineties, Gaz de France started to expand its business area and from a 100% French setting up turned to a worldwide network operation business, having to cope with different states of the art and various network states. Maintenance is a critical issue with consequences on safety and effectiveness of the energy supply for all the clients, from domestic to industrial premises.

Scheduled leak survey is a powerful tool network operators own to know the state of their networks and perform the needed corrective operations, from emergency repair to forecast replacement, to ensure the best safety level for people and the environment close to the network and to keep a high energy supply quality by maintaining the network in a good operation state.

One simple approach for network leak survey is to submit all the network to a common same survey procedure with the same survey frequency: this approach allows for very simple survey management but is not always fitted to the various states of network parts, especially if the network is composed with very distinct technologies, from various time periods and located within very changing environmental contexts. Another approach is to define more detailed maintenance guidelines, based on experience feedback as well as risk analysis issues, in order to set different network survey priority levels with associated survey frequencies. Contrary to the first approach, this is more complex to manage but allows for improving the survey effectiveness because leak survey is fitted to each network section characteristics: we can give as an example one possible organisation where some sections could be surveyed every two years whereas some others would be surveyed every three months.

With gas market openings, Authorities defined local or national guidelines in order to put network operators under harmonised conditions. One important demand is the need for traceability of the leak survey operations: network operators have to be able to report any part of survey operation. This need for traceability is one of the needs which appeared with market openings.

Eventually, urban environment, which concentrates the highest network density, is continuously changing and forces gas companies to adjust network survey techniques and procedures. Leakage sources and points of surface detection moved from the street up to the sides with both main reliability improvement and tighter road surfaces. On another hand, urban areas get more and more protected for the pedestrian safety, environment protection and the increase of life quality. Both trends introduce strong demands for the improvement and the optimisation of leak survey procedures and the effectiveness of the survey materials, which could end up to the use of new types of equipment, along with traditional ones: this could be another increasing factor for the leak survey management complexity.

Given the above mentioned context changes and considering the continuous expansion of gas distribution network to answer the increasing natural gas demand, the management of leak survey operation becomes more and more complex when gas companies wish to run an optimised leak
survey policy in order to fit their survey procedure to network characteristics. Then, leak survey management becomes a key issue and requires adapted data analysis tools and data bases to be implemented, in order to allow the operating staffs for keeping on performing their day to day duty with a always high quality and safety level.

The approach

On one hand the evolutions of the context created the need for a new generation of optimised and better fitted to environmental context survey tools, on the other hand one result of these development as well as those of the adjusted leak survey procedures bring a higher complexity for the survey management and this tends to create the need for leak survey management tools, allowing network operation teams for organising and following the whole leak survey process on their networks.

These developments have to be carried out keeping in mind some basic needs:

- To achieve the best safety and energy supply quality;
- To ensure the Complete traceability of the leak survey for the improvement of the process quality and to fit to Authority guidelines: this leads to review all the data management process;
- Improve the management tools in order to allow for continuously adjusting the survey methods to the needs of the network, increasing the safety level and controlling operation costs;
- Better focused leak survey equipment in order to fit to today’s leak characteristics;
- Give a more accurate picture of the network condition and supply critical data for maintenance operations through leak survey feedback.

Gaz de France R & D division works on two different areas to address this situation:

- Management tools to fit leak survey operations to the network needs, in order to improve the effectiveness of the leak survey: this is done on one hand by analysing on a regular basis the feedback of the leak survey process as it is performed on field and on the other the R&D Division developed better fitted leak survey management tool in order to be able to forecast, organise and follow the leak survey process while ensuring the complete traceability of the whole process: the way leak survey is managed is fed by the leak survey carrying out feedback;
- A new generation of leak survey equipment bringing traceability and data processing tools like GPS and onboard software, better fitted to modern urban environment as well as the changing leak characteristics.
**Developments : Management tools**

The management tool (or software) “PISte RSF” for leak survey has to be completely fitted to the procedures which are used within Gaz de France for this area of operation. Therefore, its functionalities and utilisation procedures entirely follow the way operators define the leak survey management. This tool position within the leak survey process is intermediate between the network data base (distribution network G.I.S. as we will see further on) and the leak equipment onboard processing software. Main characteristics of this software are the following:

- The management and forecast of the needed leak survey operations;
- The follow up of the performed operations, the progress of the survey schedule and the corrective maintenance operations, once leaks have been detected;
- The analysis of leak survey carrying out feedback in order to keep on improving leak survey management guidelines.

**Two data inputs are necessary for the leak survey management software :**

- The network data from the Gaz de France distribution network G.I.S.: this G.I.S. includes all network characteristics, from the geographic position of each part of the network to the material of the pipe or the year the pipe was laid. This G.I.S. has to be able as well to host specific leak survey parameters such as for example the survey category (priority level), the survey frequency or the reference of the route and the method which is used for surveying it;
- The definition of the maintenance rules of Gaz de France which include the leak survey: these rules have to be followed by the operational teams when they set up the management and the forecast of the leak survey. They are the procedures to be adapted to the field conditions and the capability of the teams each operational unit owns.

Once both inputs are available, the leak survey management process can be initiated.
Leak survey management

Leak survey management process is a complete data analysis, processing and preparation string. It can be considered as a kind of production line, from the G.I.S. data, going through several processes up to leak survey equipment data processing architecture and back to the G.I.S. once surveys are completed for the feedback analysis and the possible improvements.

The first step of the process is to extract all the data which will allow the operator for defining the leak survey management: it depends on the maintenance guidelines and it can be for example the material of the network (HDPE, steel,...), the year of installation and obviously the date of the last survey.

The following step is to apply the maintenance guidelines to the group of network concerned in order to set the priority level of the survey for each part of the network and the corresponding survey frequency. Following this first step, the second one will allow for choosing the type of survey which will be used for each network part: walking survey, vehicle survey or any other mean for surveying. As the picture shows, both processes result is to create different groups of network parts which will have the same leak survey characteristics.

Once all network parts have been put within one “leak survey characteristic” group, two operations can be performed:

- Set up the survey schedule depending on each priority levels and the date of the last survey for each concerned sections;
- Design for each group the route the field teams will follow to perform the survey on the most effective way. On this way, field operators don’t have to think about the way to follow during the survey and they can focus on the survey, the equipment and the leak detections which could occur.

A key element of this process is the use of geographic data and maps in order to lead the process with geographic restitutions at each step: operator can either work with data tables or data maps, whichever is more suitable to the way he works.
At this step of the process, the management of the leak survey operations has been set up and the data has been prepared to be used within the onboard software of the leak survey equipment. The next phase is to perform and follow up the leak survey operations.

**Leak survey follow up and feedback analysis**

Once survey operations have been carried out, all the data coming back from the onboard software is collected by **PISte RSF** in order to perform two different phases:

- Launching the corrective actions in case of leak detection;
- Gathering and processing the acquired data for traceability, schedule updating and keeping the performed route as a basis for the next year route definition

Day after day, once each operation of leak survey is performed and the following corrective actions are carried out, the network operating team can update the progress of its network survey schedule and make decisions for adjusting the task force to be run for ensuring the schedule to be respected at the end of the period. This last operation is allowed thanks to the data feedback which is sent to the distribution network GIS and which is stored within special data attributes within the G.I.S..

After each survey period, leak survey feedback is processed and the potential improvements for the next period survey procedures are defined. Year after year, survey results are analysed and compared and, once the particular variations eliminated, it is possible to evaluate the impact of the successive improvements.

The management tool **“PISte RSF”** should be deployed within the next years, after have been experimented within several network operations units.
Developments: New generation of survey equipment

Onboard data architecture

The management tool “PISte RSF” would not be useful without a set of fitted onboard leak survey data processing architecture and especially leak survey equipment onboard software called Géofuite. This software added value is on several points:

- Sharing data with the tool “PISte RSF” in order to use the routing data which is prepared by “PISte RSF” and sending back to “PISte RSF” all the traceability data which has been acquired during each survey operation.
- Allowing for the leak survey operator to focus on his survey and process the detections on the most effective way, with no additional obligations such as keeping a trace of the route followed or noticing any unexpected event which could occur during the survey for example.

Onboard data processing architecture is composed with three key elements:

- The GPS for the positioning of the survey equipment information;
- The gas detector;
- The software which gathers the signals sent on one hand by the GPS and on the other hand by the detector (gas concentration, defaults,…) during the survey. Additionally, this data processing architecture allows for performing some quality testing, at the beginning, during and at the end of the survey, especially on the detector, in order to guaranty the quality of the data.

Where operators used to work with paper maps and written routing, they will now follow the routing which continuously appears on the screen of the onboard computer as long as the vehicle or the survey equipment (portable detector) follows the forecast route. In order to help the operator to follow the defined routing, a vocal device is included in order to give the driver all the needed directional information during the survey.

Figure 1: onboard data processing software « Géofuite » interface
Vocal routing as well as traceability of the followed route is ensured with the help of a G.P.S. receiver: on this way, any information is linked to the actual survey equipment position when the information (event, gas detection, equipment default,...) occurs. Every second, the GPS position is linked to, at least, the actual gas concentration which is detected by the detector and this information, with some others, is recorded to the survey traceability files.

Once any gas concentration (1ppm sensitivity threshold) is detected, the onboard system gives several alarms (window on the screen, sound from the computer) to warn the operator about this new event. At this step, the traceability file is enriched with this specific “gas detection” data.

At the end of the survey, all information acquired is gathered and put within a compressed file, to be transmitted to the network operation team in order to be processed and analysed.

A first experimentation release of this onboard processing data architecture has been developed and successfully tested by Gaz de France R&D during years 2003/04 (5500 km of surveyed mains). This architecture is operational since 2005 on the last generation of survey vehicles for Gaz de France Distribution network: the onboard data processing system has been adapted to operational configuration with the survey vehicle supplier.

Leak survey detection equipment

One of the last points to be addressed consists in the answer to be given to the changes which occur within the environment of the distribution networks (especially in urban areas) and their impact on the leak survey carrying out.

In order to improve the quality of the detection (sensitivity, response delay, methane selectivity) during the surveys, Gaz de France collaborated with several optical detectors manufacturers since the end of the nineties. The main concern of Gaz de France R&D team in this field was to be able to find the good product and achieve a reliable test set in order to be able to qualify this good product to come for operational utilisation. On this way, Gaz de France R&D developed a new set of tests in order to qualify some unusual characteristics such as signal stability on time, resistance to vibrations, ...

First attempts were not very successful but in 2005, a new type of detector came out with a laser diode based detector (1.65 \( \mu \text{m} \) wavelength) which went successfully through the qualification process, allowing for an operational utilisation on Gaz de France survey vehicles.

The advantages brought by the optical detector for the operators is simplified utilisation procedure, with no warming time, a simplified testing procedures and equipment (tests are operated from the onboard software, only one gas bottle is used,...) and a very limited size, allowing for an installation in smaller and then better fitted to urban environment vehicles. Furthermore, the very short response delay (half of that of flame ionisation) allows for surveying faster: survey maximum speed rose from 20 to 40 km/h which allows for a better productivity and moreover a better safety for the operators because the vehicle is not that slow anymore, compared with the other vehicles on the same road.

Six survey vehicles of this last generation are being operated by Gaz de France leak survey teams and six others are about to be deployed in 2006, in addition to the eight last generation F.I.D. which will be upgraded with the on-board data processing architecture. At the end of 2006, 20 vehicles over a fleet of 27 will be equipped with this traceability and productivity architecture.
Once the onboard data processing architecture has been implemented on vehicle, the aim is to develop the same application on the other equipments used for leak survey which are at the moment those used for the walking leak survey. But when defining the tools for the future of the walking survey, some other parameters have to be considered before starting any development:

- Areas which concern the walking survey are very often difficult to reach, dense urban centers, pedestrian areas;
- Walking survey requires more “detailed” survey than the vehicle due to all the parts of the networks to be surveyed (main, service, meter cabinet, underground valve,…);
- Walking survey is very much time consuming compared to vehicle.

For these reasons and because improvement of the walking survey has not been very much investigated until the last few years, it appears that the walking leak survey deserves a more ambitious approach with a goal which would be beyond the “simple” traceability application from the vehicle to the walking survey equipment.

**Several options are available at the moment for improving the way the walking survey is performed:**

- Using remote detection devices, based on harmless laser beam reflection to cover the close area: these devices allow for covering wider areas compared to a “conventional” portable detector;
- Using a mobile application of the previous remote system on a vehicle so as to carry out the walking survey and the vehicle survey at the same time;
- Using small innovative and low polluting vehicles in order to survey the difficult to access areas while improving the effectiveness of the walking survey (for example in some pedestrian areas) where areas are wide enough to allow for such a device to be used (some considerations have to be taken for not disturbing usual area activity).

During the last two years, Gaz de France R&D division started to work on the potential utilisations of the remote detectors. Two of these concern the distribution network:

- Walking leak survey of gas distribution network;
- Survey of all elevated network parts (outside risers, mains installed on bridges).

Leak survey of distribution network gives a good potential for the use of remote detection systems. The question of the optimisation can be further investigated with the evaluation of the mobile application of such systems and/or the use of special vehicle for difficult to access areas.

The tests of these last applications are about to start but a special attention will have to be brought to the control of the ability of such optical devices to withstand the specific “mobility” constraints (vibrations in particular, lifetime expectancy, signal stability,…).

If the testing phase is a success, the potential for improvement of the leak survey, and particularly that of walking survey, is certainly very high.
Results
Although several promising developments are still to be confirmed or industrialised, this new approach for leak survey and the related innovative systems already give productive results in the following fields:

- **Effectiveness of the leak survey for safety increase**: this is achieved because of the better fitted survey management and the continuous procedure adjustment. As well, productivity of the leak survey is dramatically increased thanks to the reduction of survey management time, survey organisation optimisation and more effective field equipment which allow to improve survey output;

- **Maintenance operation costs decrease**: methane selectivity dramatically reduced the number of false alarms, the expansion of survey area allows for detecting more leaks and reduce third party calls. This last point leads to perform more scheduled maintenance and less emergency operations;

- **Process safety level and reliability improvement**: better fitted equipment for environment conditions, less maintenance operations, less downtime. On the same way, equipment is easier and less tiring for the teams, allowing for work incident decrease.

Conclusions
The advantage of the global approach for the improvement of the leak survey process is that each equipment is considered as a part of the global system and all needed communication phases and data exchange are forecast from the beginning. The allows for dramatic time savings when developing new equipment and a better fitted system.

The complete data management chain ensures the whole survey traceability and the day to day survey feedback which is processed allows for continuous improvements in order to offer an always higher safety level and supply quality.

The use of G.I.S. functionality gives the ability to process a great amount of data with the maximum effectiveness, saving important time amount for the benefit of the field leak survey carrying out.

Nowadays, some developments are still to be lead but the global system is on the way and the benefit should increase within the coming years.