EXPERIENCE WITH INFRARED LEAK DETECTION ON FPL SWITCHGEAR

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INTRODUCTION:

Sulfur hexafluoride (SF_6) is an excellent dielectric gas that is used extensively in high-voltage power equipment. It is chemically inert, nonflammable, nontoxic, and non-corrosive under normal conditions. The power industry is a major user of this gas.

ENVIRONMENTAL:

Studies have found SF_6 23,900 times more effective at trapping infrared radiation than CO_2. Its atmospheric lifetime is estimated at 3,200 years. At the 1997 Kyoto Japan summit, SF_6 was among the six greenhouse gases targeted for emissions reduction. The Environmental Protection Agency (EPA) has classified it as a "greenhouse gas." As such, EPA is interested in controlling SF_6 release to the atmosphere and promoting competent SF_6 management.

EPA has joined in "SF_6 Emissions Reduction Partnerships" with many of the major U.S. utility companies. A memorandum of understanding (MOU) is drawn up between the EPA and the utility. Partnership requirements include:

- Maintaining **ACCURATE INVENTORY OF SF_6**
- **MONITORING** and **REDUCING** the **OVERALL SF_6 LEAK RATE**
- Implementation of **SF_6 RECYCLING**
- Tightly **MANAGING** the use of SF_6
- Yearly reporting of SF_6 **EMISSIONS**

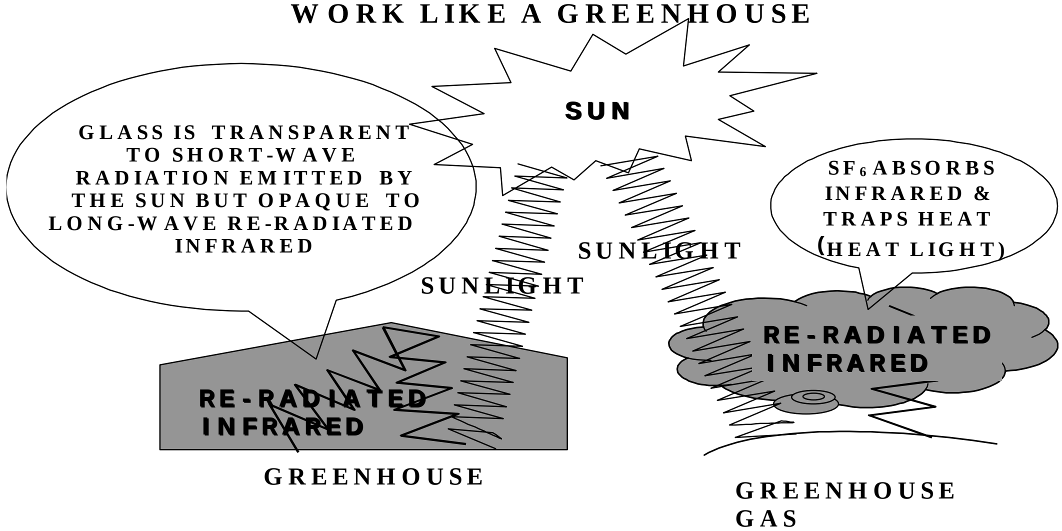
GREENHOUSE EFFECTS:

High temperatures such as those found on the sun produce short-wave radiation. A small percentage of this energy hits Earth. This radiation is absorbed; some of it is converted to heat and re-radiated as long-wavelength radiation in the form of infrared radiation (heat light).

In a greenhouse, glass is fairly transparent to short waves, but to longer waves it tends to be opaque. Thus, the inside of a greenhouse warms because of the trapped infrared. SF_6 tends to absorb and trap infrared just as in a greenhouse; in this case, the heat warms the atmosphere.

GREENHOUSE GASES

WORK LIKE A GREENHOUSE

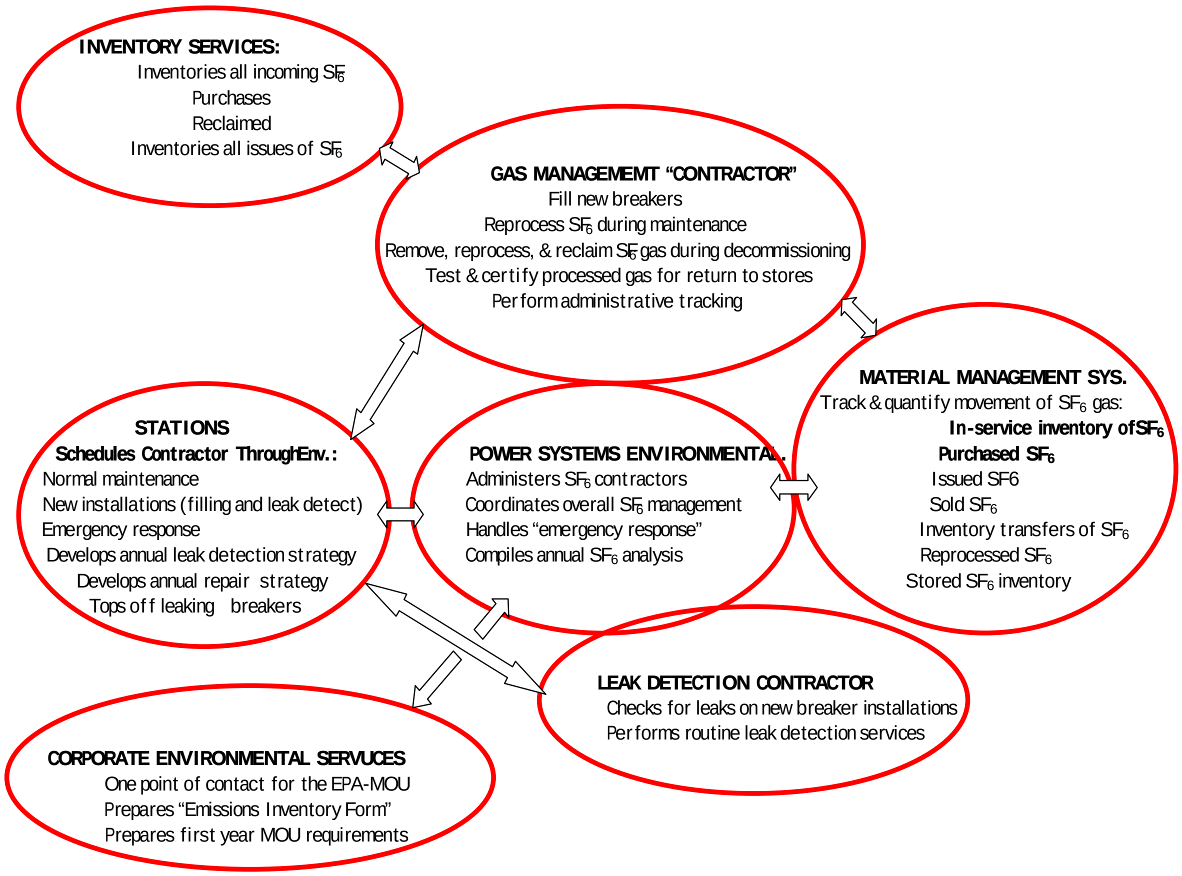


CURRENT SITUATION:

To comply with the Partnership, utilities are faced with two primary decisions: How to effectively manage and document the use of SF_6 on the system, and how to effectively detect SF_6 leaks. To answer these questions, FPL did extensive analysis.

ANALYSIS:

Economic analysis indicated that outsourcing both SF_6 management and leak detection was cost-effective. A management interaction diagram was then created to aid in developing structures, procedures, and bid specifications.



SF_6 LEAK DETECTION:

In the area of leak detection, "Corporate Philosophy" was NEGOTIATED between departments. Agreement was reached on the following:

- All new breakers will be leak checked after installation.
- The existing population of SF6 breakers will be periodically checked.
- Equipment needing periodic filling will be documented and leak checked.
- Permanent fixes are preferred to temporary repairs (epoxies, etc.) where reasonably possible.
- Gas imaging technology will be used.

GAS IMAGING TECHNOLOGY:

Traditional leak detection methods using soap and sniffing equipment require that the breaker be removed from service. Waiting until data are collected on the periodic filling to determine leaking breakers takes time and does not provide information on where the leaks are. Some form of laser-based, remote sensing technology is generally needed if a large equipment population is to be tested in any reasonable time frame.

The technology "chosen" is known as backscatter absorption gas imaging (BAGI). This remote sensing technique is designed for the sole purpose of locating leaks or tracking gas clouds (McRae, 1993). The BAGI technique is a qualitative three-dimensional vapor visualization scheme that makes a normally invisible gas leak “visible” on a standard video display. The image of escaping gas allows the operator to identify the source of the leak and make a fairly accurate determination of its intensity. Gaseous leaks are detected and displayed in real time, but accurate determination of volume is not possible. This was not seen as a problem because the weight of SF_6 gas used to top off leaking breakers is being tracked.

This technology was first developed for the Naval Sea Systems Command at the Lawrence Livermore National Laboratory. The idea was for the protection of sailors during initial surveillance of disabled marine vessels for the presence of toxic or flammable vapors. The system was patented under BAGI technology (US patent #4,555,627) and is marketed under the trademark “GasVue.”

The advantage in using laser imaging systems is multifaceted: the exact location of leaks can be determined; the intensity of a leak is visible; equipment can remain in service while being tested; testing time is greatly reduced; and video documentation of the leaks provide positive evidence.

Figure 1 depicts how a laser camera illuminates the object under inspection, producing an infrared image from the backscattered laser light in much the same way that backscattered sunlight produces an image for a conventional TV camera. The detector in the laser camera is filtered so that it responds primarily to the wavelength of the laser light and ignores essentially all of the background thermal emission. Because there is no SF_6 gas in the top view, the TV image is just of the background objects. However, when SF_6 gas is present, as shown in the bottom view, it absorbs the laser light making the gas appear as a dark cloud. The higher the gas concentration, the greater the absorption, and the darker the gas cloud. In this manner, the normally invisible gas and its origin are visible on the TV monitor.

FIGURE 1

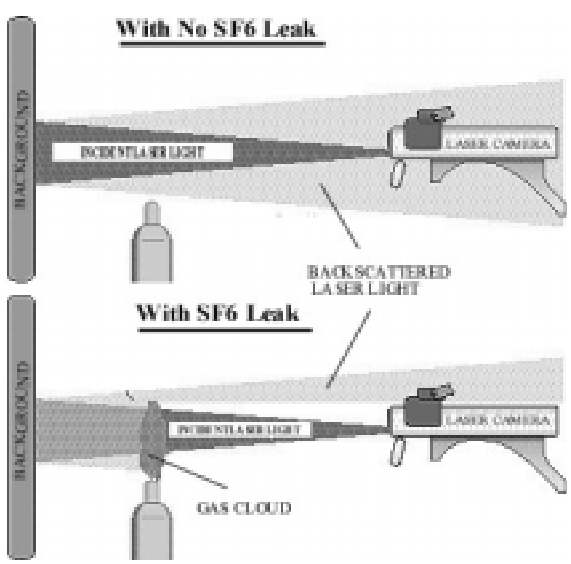
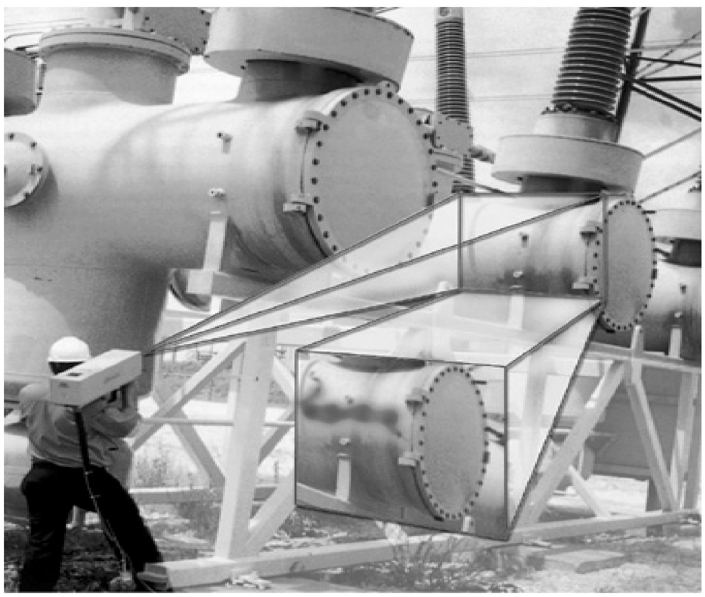


Figure 2 shows the inspection of an SF_6 circuit breaker with laser system. The infrared image of the area under inspection is shown as the black-and-white inlay. This inlay is the same image that the operator will see in the laser camera's viewfinder. In actual practice, the motion of the leaking gas plume makes the leaking area noticeable. Obviously, this allows for very rapid inspection of the equipment while in-service, and the ability to pinpoint extremely small leaks. Furthermore, the results can be documented on video.

The technology does have its performance limits. The range of detection is generally between 20 and 30 meters but can be limited by weather (wind in particular). There must be a "reflective or backscattering surface" behind the leak, so it is not possible to visualize a gas plume against the sky. Too much free SF_6 will obscure the leak if the area is indoors and the leaking is so bad that a "high density of SF_6" surrounds the leaking area. The most favorable results have been obtained when the leak source was as close as possible, with low wind speed, and with the escaping gas coming directly at the laser cameras. As a final note, our field results have demonstrated that none of these limits caused insurmountable problems.

FIGURE 2

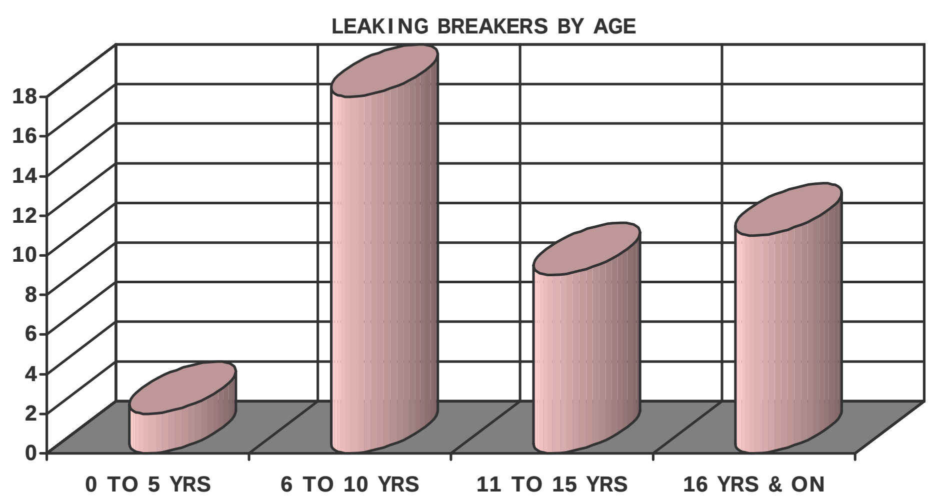


THE EQUIPMENT:

Machines now use CO_2 laser power and video imaging camera equipment. The base unit and camera equipment are bulky, but research is being done to reduce the size (see Figure 3).

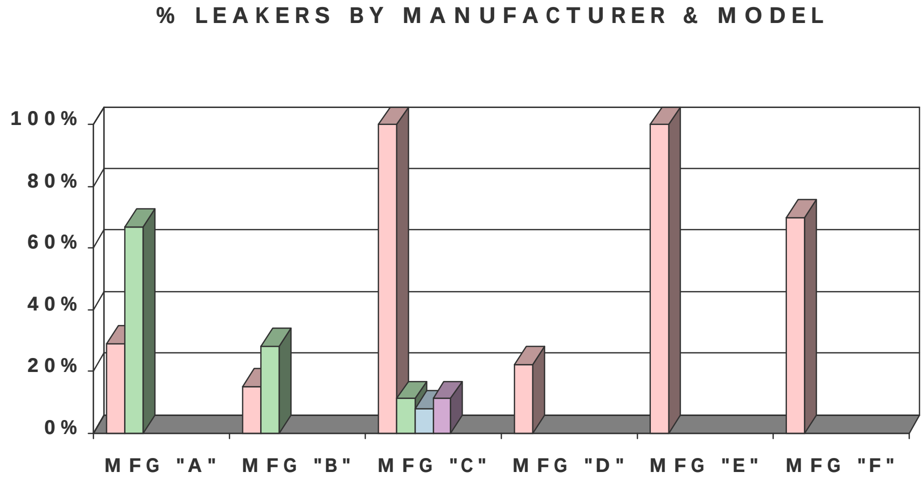
FIGURE 3

FIELD RESULTS:



AS ANTICIPATED, THE INFRARED LEAK DETECTION PROGRAM HAS PAID OFF:

- Within **4 months of implementation, 460 breakers** had been tested.
- **9% (40 breakers)** of the breaker population were found with **detectable leaks**.
- **85% of the leaking breakers** were found to have **significant** leaks and had to be referred to "OPERATIONS" for scheduled repairs.
- **15% of the breaker leaks** were **minor** enough to repair on the spot by the contractor.
- **5% of the leaking breakers** were new and still within the **warranty period**.



WHERE WERE THE LEAKS FOUND?

- **62%** of the leaks were found around **fittings, piping connections, & gage connections.**
- **16%** were found around **access gaskets**.
- **12%** were found on **bushing seals**.
- **5%** were found around **drive rods**.
- **5%** were found at **welds.**

CONCLUSIONS:

- "OUTSOURCING" LEAK DETECTION HAS BEEN ADVANTAGEOUS IN BOTH THE AREAS OF COST AND SPEED OF PROJECT COMPLETION.

- INFRARED LEAK DETECTION HAS ALLOWED FOR IDENTIFICATION OF SF_6 LEAKS WHILE EQUIPMENT IS STILL IN-SERVICE

- IN MANY CASES, INFRARED LEAK DETECTION HAS IDENTIFIED LEAKS PREVIOUSLY UNDETECTED USING TRADITIONAL TECHNIQUES.

- RESULTS HAVE BEEN AS ANTICIPATED—GOOD—AND ALL LEAKING BREAKERS HAVE EITHER BEEN REPAIRED, SCHEDULED FOR REPAIR, OR ARE SCHEDULED FOR REPLACEMENT.

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