of the "Saddam Hussein Justice Commandos." According to the caller, the attack was in retaliation for the "unprovoked U.S. aggression against Iraq" and he warned that further attacks would follow.

Sabotage

It was the Bush administration's darkest nightmare, and that of every law enforcement and security specialist in the country: planes blown out of the sky, top officials gunned down, car bombs going off on crowded American streets, and even catastrophic attacks against U.S. industrial facilities. Experts predicted a wave of terrorist incidents against U.S. targets, both at home and abroad.

Spurred by reports in the media, the public quickly became alarmed. Many had visions of hordes of black-clad Ninja-like terrorists storming U.S. beaches to murder, rape, and loot. During the Gulf crisis, Americans stayed away from airports in droves and saw what they presumed to be Iraqi terrorists behind every bush and under every bed. Some people hoarded food, some purchased guns, and in Toledo, Ohio, there was a run on gas masks.

However, the wave of terrorism in the United States that had been forecast did not materialize. Nevertheless, the fear that Saddam Hussein might open a terrorist "second front" was not without foundation. More than 200 terrorist attacks occurred elsewhere in the world during the war against Iraq, a substantial increase over the same period during the previous year.

In reality, the end of the war, as Pentagon and State Department officials have long warned, may represent just the beginning of the real terrorist threat. The war re-energized every radical and terrorist organization in the Middle East, and may well spawn a generation of terrorist attacks designed to "avenge" Saddam Hussein and those, like the Palestinians, who looked to him as a hero. Moreover, at this writing, Saddam is still in power and licking his wounds, and Baghdad remains one of the "capitals" of international terrorism.

Just as Libya has used terrorism to "punish" the United States for its April, 1986 raid on Tripoli and Benghazi, so too is it likely that the Iraqis will strike back at the U.S. using terrorist surrogates to avenge the "humiliation" that they suffered in the recent war.

Thus, critical industrial targets in the United States may be more at risk than ever before, and steps must be taken to assess vulnerabilities and correct them before disaster strikes.

Petroleum systems and related petro-chemical plants are among the most vulnerable industrial facilities in the world to wars, terrorists, foreign saboteurs, and industrial strife. As Operation Desert Shield/Desert Storm demonstrated, the sabotage of energy facilities is not terribly complicated and can have a devastating impact on whole economies. During the recent Gulf War, Kuwait's entire oil infrastructure, including more than 650 oil wells, was sabotaged by Iraqi forces and several large oil releases created enormous slicks in the Persian Gulf that fouled beaches and sea habitats.

A survey of recent attacks on energy facilities included the following.

- In late September and early October, 1982, ten bombs were discovered at a Gulf Oil Chemicals Co. refinery in Baytown, Texas. They had been hidden in the facility as part of a $15 million extortion attempt.

- A NATO fuel pipeline was bombed on December 12, 1984, in southern Belgium. Credit for the attack was claimed by the Communist Combatant Cells (CCC).

- Oil facilities were bombed by saboteurs in Kuwait on June 18, 1986, nearly bringing "Kuwait's oil exports to a standstill." Two of the bombs damaged manifolds where crude oil is blended on its way to tank farms and the third device ignited a high-pressure well.

- Pipe bombs were discovered at a chemical storage facility in Norfolk, Virginia, on February 4, 1991, during the war with Iraq. Several men subsequently were arrested and convicted as part of a conspiracy to acquire the insurance money.

Attacks against the global energy infrastructure are increasingly common. There is an average of 1200 terrorist and other attacks a year against energy facilities throughout the world (see Appendix 3). During the 1980s, 85 of these attacks were directly against refineries, some of them with HF alkylation units.

From the standpoint of terrorist attacks, pipelines, terminal areas, electric power pylons, and tanker trucks generally are considered more vulnerable targets than refineries, but most refineries are not very well protected (See Appendix 4). Because of their accessibility, refineries are relatively easy to sabotage and disrupt. Indeed, the average refinery can be put out of commission with the strategic placement of weak explosives. Even more alarming is the prospect of using explosives to create a disaster with secondary and tertiary consequences, such as the release of a toxic chemical like HF. In other words, a terrorist possessing only a small amount of explosive is likely to ferret out targets where the careful placement of those explosives is likely to create a much larger disaster than could be produced solely from the blast effects inherent in the device [bomb] itself.

All that is required to bomb a refinery facility, even the alkylation unit, is access to the plant itself and knowledge of where to place the explosives. While the previous scenario may seem far-fetched to some, access to many critical energy facilities and refineries is as easy as walking through the front gate. During the recent war with Iraq, a number of refineries surveyed by security specialists had little or no security at the front gate or entrance. In other cases, there were holes in the perimeter fences or fences so low that they did not represent meaningful barriers to any saboteur. One security specialist described a three-and-a-half foot chain-link fence protecting one refinery, which had a fire hydrant next to it that could be used as a step to climb over the fence.

According to David Chatellier, a former U.S. special operations veteran who has done security assessments for the petroleum industry and carried out many simulated attacks against refineries, sabotaging a refinery's alkylation unit is not particularly difficult. "The holding containers are normally elevated above the ground and are sometimes color-coded for safety purposes," he observes. "Plus, they are almost always capable of being identified from outside a facility's perimeter. But the primary target is the alkylation reactor. This is where the acid is placed under some measure of pressure and will do the most damage to the refinery overall. A shaped charge can be placed on a primary pipe or on the reactor and will result in the greatest release of HF. A platter charge directed at the chiller also would produce a release.[37] Given the complexity of refineries, if the explosive device is painted the same color as the surrounding pipes and machinery, or designed to look like a dummy piece of equipment that would normally be found on the site, it will be almost impossible to detect before it detonates.

The disaster can be compounded by "cutting off the water supply to the refinery," says Chatellier. "It's almost always provided by an outside source and is never protected," he adds.[38] Indeed, even if the alkylation unit had a water mitigation system, it could be incapacitated by striking simultaneously at the water source. This could be accomplished with explosives or simple sabotage.

Even more alarming, the master terrorist of the future is far more likely to be armed with a personal computer than with guns or explosives. Someone who can infiltrate a refinery facility, either as an employee or posing as an employee, and who knows something of its operation, may be able to produce catastrophic failures and releases of toxic chemicals simply by operating a computer keyboard.

Recent spy trials and sabotage cases in the United States are not reassuring when it comes to the quality of access security, even at some of the country's most sensitive facilities. In one case, employees of a highly-classified facility substituted the photos on their I.D. cards with those of Libyan strongman Muammar Qaddafi and, in another case, a chimpanzee, and security guards repeatedly failed to detect the inconsistency. In another instance, employees signed into a facility as "Abu Nidal," "Yasir Arafat," and "Muammar Qaddafi," and their phony signatures aroused no suspicion. Not only is there little or no background screening of employees at oil and petrochemical facilities, but once inside, the possibilities for sabotage are extensive.

Few refineries have undertaken adequate security precautions to thwart most acts of terrorism, sabotage, and violence. A survey of refinery security in the United States indicates that it is one of the most poorly secured industries in the United States, and that any knowledgeable saboteur would encounter few obstacles that would prevent him from engineering an intentional release of HF from an alkylation unit.

During the recent Gulf War, for example, a number of refinery complexes employed outside consultants to examine their security arrangements. According to reports compiled by several consultants, physical security is "antiquated, ineffective and virtually nonexistent" at the facilities surveyed. "The security force is untrained and unprepared to locate, confront or control a real security problem or crisis," concluded one report, adding that, "Internal security of personnel in key positions [also] is insufficient."[39]

At a Houston-area refinery complex employing HF alkylation, investigators found such security lapses as:

> "No fence or deterrent on north perimeter allowing unrestricted access."
>
> "New fence installed on south perimeter [11′] joins 4′ high fence which offers little or no resistance to access."
>
> "[deleted name] perimeter has no fence and offers unrestricted access."
>
> "No sensors or CCTV are used, no alarm system used. Security is dependent on a single roving patrol for the plant and the corporate officials."[40]

The same story was repeated at a Texas City refinery employing HF alkylation:

> The fences are in "bad shape." "Some sections are buried and

others are missing."

There is "no guard at the main gate." The gate is monitored solely by CCTV. Visitors are expected to phone the central security office and report in.

There are "no alarm sensors or alarm systems, only a single roving guard . . . All facilities are easily accessible on numerous fronts and offer little deterrent to penetration or attack."[41]

Security consultants found the same problems at other refineries in Louisiana employing HF alkylation. "The overall security situation in Louisiana is almost identical to the situation in Texas," they wrote in their final report. "There are apparent inadequacies on all sites with the common denominator being predominantly a lack of training. Louisiana sites also suffer inadequate physical security."[42]

What is most disturbing about the above reports is that the surveys were conducted at a time of conflict, when there was a grave national security threat from international terrorism. U.S. airports, by contrast, were at their highest sustained level of security (Level Four) in the nation's history. Despite the threat, the oil and petrochemical industries failed to take appropriate measures to protect their vital infrastructure assets, and can only be described, in retrospect, as "sitting ducks." While the United States escaped the kind of terrorist attacks that had been feared, terrorism was up sharply throughout the world during the war with Iraq. There were numerous unsuccessful threats made against various petroleum refineries in the U.S., as well as the attempted sabotage of at least one European energy facility. This incident was the bombing of an oil storage facility at a U.S. Naval facility in Rota, Spain, on Feb. 18, 1991.

No more effort, expertise, or explosive would be required to sabotage an H_2SO_4 alkylation unit than its HF counterpart. Refineries employing sulfuric acid aklylation are no better protected or operated than those using HF. The difference is that the consequences arising from such an act would be far more serious, and potentially deadly, in the case of HF. Thus, refineries with HF units are vastly more inviting targets for sabotage than are those relying on sulfuric acid alkylation. There is even less logic to introducing HF alkylation units into the developing world, especially nations and regions characterized by inherent instability and conflict. The Middle East, for example, contains more than two-thirds of the world's oil reserves, yet it is the most violent region on earth. In addition to countless bloody revolutions, civil wars, coups d'etat, border disputes, military interventions, assassinations, and terrorist incidents, since World War II the Middle East has witnessed four major Arab-Israeli wars, the eight-year long Iran-Iraq war, the protracted civil war in Lebanon, and the recent Gulf conflict in which Iraq – following its invasion of oil-rich Kuwait – was defeated by a combined Western-Arab Coalition, led by the United States.

Interestingly, more than half of the world's major terrorism-sponsoring states are located in the Middle East, and at least three of them – Libya, Iran and Iraq – are significant oil producers. Syria, another leading terrorist-sponsoring state, has some limited oil and natural gas production. There is little question but that such nations understand refinery vulnerabilities and can easily train their forces to target such facilities. Moreover, their operatives can easily blend into the oil industry environment without attracting significant attention.

These same countries, along with such other terrorist-sponsoring states as North Korea, also are developing sophisticated chemical technologies that can be used in the eventual manufacture and stockpiling of chemical weapons. As a consequence, terrorists may be particularly well-equipped to attack the petroleum and petrochemical industries.

It was a perfect night for mayhem. Not too hot, not too cold, with a light breeze blowing from the west. The HF should vaporize almost instantaneously, thought Ansel Hand, a malevolent smile spreading slowly along his thin lips.

He turned around and grinned at his three companions. They were all members of an Arkansas-based white supremacist organization known as the American Identity Warriors, which embraced a vicious racist and antisemitic agenda calling for a "war" against all "unwholesome" elements in America.

All four men were dressed in black from head-to-toe. Even their faces were blackened. They all wore sidearms, and Cal Spooner was also carrying an assault rifle.

The ground crunched softly beneath their boots as they crossed a trash-strewn vacant lot, taking pains to stay in the shadow of an abandoned warehouse that abutted the old railroad yard. They had left their van a short distance away, in a junkyard full of derelict autos and trucks where it would not look out of place.

"We sure gonna have us some fun tonight," said Lyle Tucker, as they scaled a chain-link fence and approached a maze of railroad tracks.

"Let's keep it down," ordered Hand.

They halted and Hand gazed slowly up and down the tracks and around the railroad yard for any sign of movement. Nothing. So far, so good.

To the north, on the other side of the yard, was a poor, largely black neighborhood, full of dilapidated row houses and tenements. Although it was after 3:00 a.m., there was still a good deal of activity on the streets, and Hand and his confederates could hear laughter, mixed with curses, in the distance.

Suddenly, Hand saw what he was looking for. He pointed at several tank cars on one of the sidings.

"There they are," he whispered. "Just where Fred said they would be."

The four men approached the tank cars apprehensively. Hand pulled a piece of paper out of his pocket and shined a small pen light on it, comparing the numbers on the tankers to the one on the paper.

"Bingo," he announced, switching off the light and walking over to the third car in the line. "It's this here one."

He pulled a pack off his back and dug into it, retrieving a small shaped charge and a timing device. It was just powerful enough to punch a good hole in the tank car without staring a fire that would consume the hydrofluoric acid inside.

He expertly mounted the charge on the tank car, as he been taught to do by a member of the Aryan Nations movement, a former Special Forces demolition expert. Until he had been killed in a shootout with police near Seattle, the Aryan Nations man had held an annual three-day training session on explosives for other like-minded political extremists in northern Idaho. Hand had attended three sessions and supplemented his knowledge with bomb-making manuals he purchased through the mail. There was an old quarry near his home in Arkansas where he practiced blowing up things.

Finally, everything was ready.

"Get goin'," he ordered the other men, and they began retreating back across the rail yard toward the chain-link fence.

Hand peered through the darkness one last time to ensure that nothing was amiss, then twisted the handle of what looked like an egg timer and sprinted off after the others.

Once over the fence, moving rapidly, they retraced their route across the vacant lot, back to the junkyard, where they piled into the beatup van. As they pulled away, they heard a muffled bang in the direction of the rail yard. Seconds later a frothing, foaming cloud of hydrofluoric acid began spewing from the tank car and spreading, like a tidal wave, in the direction of the densely-populated neighborhood on the other side of the tracks, engulfing everything in its path.

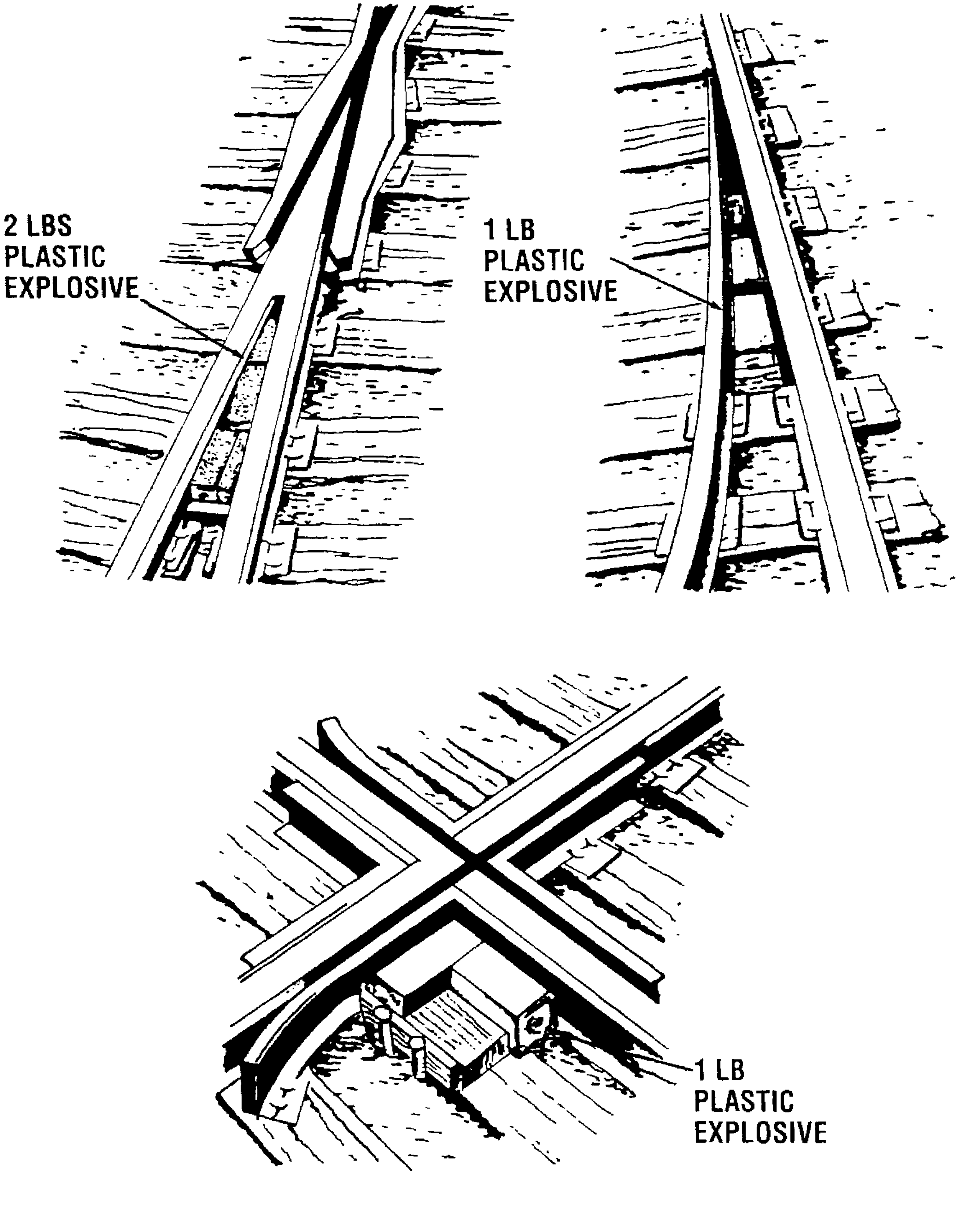
By morning, more than a thousand people were dead and 6000 had been treated, or were awaiting treatment, at local hospitals, which were jammed to capacity. As word of the disaster spread and it became clear that a black neighborhood had been specifically targeted by the terrorists, riots and disturbances broke out in more than a score of cities.[43]

Transportation

Hazardous chemicals are moved through American cities and other heavily populated areas every day. Some of the chemicals are the same as those used on the battlefield during World War I, but are referred to by their innocuous industrial names so as not to unduly alarm the public. Phosgene, for example, which accounted for tens of thousands of injuries when used by the Germans against the Allied Forces, is known today as carbonyl chloride, and has dozens of industrial applications. As a result, it regularly is transported throughout the United States by truck and rail. Similarly, few Americans recall that chlorine, as noted earlier, also was used as a chemical agent during the First World War by the Germans.

Although they represent a very small percentage of the total volume of materials transported, every year there are thousands of rail, barge, pipeline, and tanker truck accidents in the United States, and many more thousands abroad. Rarely does a day go by without some kind of accident somewhere necessitating the evacuation of large numbers of people living in the adjacent area. In early July, 1987, for example, a truck in Japan rolled on a busy highway, spilling 5,000 pounds of HF, which rapidly formed a deadly vapor cloud. Although no one was injured in the incident, twenty-one families living in the immediate area were evacuated and the highway was closed for 13 hours

In this connection, transportation of hazardous acids like HF and H_2SO_4 involve many potential dangers. Fresh acid must be transported to the alkylation plant and, most often in the case of sulfuric acid, the spent acid must be returned to a H_2SO_4 plant where is is regenerated. HF ordinarily is regenerated on site. Thus, relative to refinery operations, far more sulfuric acid must be transported than HF. But, as Professor Lyle F. Albright has concluded, ". . . the dangers if an accident should occur are drastically greater in the case of HF. HF liquid is transferred by either tank trucks of up to 20 tons capacity (about 5000



Demolition of railroad switches, frogs, and crossovers.

gallons) or tank cars of 20-91 tons capacity (about 5000-22,000 gallons). An accident with such a truck or railroad car in a metropolitan area has the potential based on tests in the Nevada desert of making Bhopal look like peanuts."[44]

Research by the South Coast Air Quality Management District found derailments to be the greatest source of concern with respect to HF releases. In a typical year, there were 2649 separate rail car derailment incidents in the United States.[45] In 1990, thirty-five rail car derailments involved hazardous or toxic substances. In addition to accidents, rail cars transporting HF to refineries are extremely attractive terrorist targets

At most refineries with an HF alkylation unit, HF is delivered by tank car or tanker truck to the storage tanks. From a saboteur's point of view, HF is most inviting as a target in the tank car or tanker truck. Despite the hazards associated with HF, there is no evidence of any special physical security precautions being taken to protect the transport of HF by rail or tanker truck.

Special operations veterans contend that trains are extremely easy targets. According to David Chatellier, "A relatively small explosive charge of two pounds or less is all that is needed to demolish switches, frogs, and crossovers on train tracks. The destruction of any one of which would result in the derailment of a train." He goes on to observe that in many cases it would not even be necessary to derail a train to cause an HF release. "Rail cars are normally stored on side tracks in isolated areas that are easy to access," Chatellier maintains. "The placement of a shaped charge to open the car or the opening of a valve takes only a matter of minutes. Water probably would not be readily available to control the vapor."[46]

Tanker trucks, similarly, present little challenge to knowledgeable saboteurs. Tanker trucks are easy to sabotage, hijack, or simply steal from parking areas. A 7.62 mm standard NATO rifle round will penetrate most tankers with ease, and contemporary terrorists have a wide variety of even more powerful weapons including rocket-propelled grenades (RPGs) and various anti-tank weapons at their disposal. Explosives, moreover, can be surrepititously planted on trucks. "Truckers always stop at truck stops to eat and leave the trucks unattended for the most part," says Chatellier. "It is not difficult to place a timed or remotely detonated explosive charge on a truck. This way, the attacker determines where the HF will be released and when."[47]

Such tactics are hardly secret. Not only are they routinely taught to special operations forces throughout the world, but they are available in publications that can be purchased through the mail. Such information can even be obtained from computer bulletin boards in the United States. According to a recent report, one computer bulletin board specifically offered "bombmaking and train derailment tips."[48]

Nor are the weapons and explosives needed to carry out energy-related terrorist strikes difficult to obtain. As terrorism-expert Brian Jenkins has observed, the "instruments of warfare once possessed by armies" are now available to gangs. Few terrorists or even labor racketeers want for weapons, and their arsenals contain everything from grenades to explosives.

In the final analysis, the transportation vulnerabilities cited above lend strong support to incorporating spent acid regeneration plants on site for both HF and H_2SO_4. Nevertheless, the transportation phase cannot be completely eliminated and, therefore, increased safety precautions should be adopted governing the transport of superacids and other hazardous chemicals.

The Cost Factor

Economic considerations traditionally only have been one factor in the choice between the competing HF and H_2SO_4 alkylation processes. Oil industry politics and market relationships have played a role, as has the location of the particular refinery.

Advocates of the hydrofluoric acid alkylation process maintain that it enjoys a substantial cost advantage over sulfuric acid alkylation. Proponents contend that HF alkylation requires smaller and simpler reactor designs, the use of cooling water instead of refrigeration, smaller settling devices for emulsions, a lower volume of hazardous waste, and on-site regeneration of the spent acid. For these and other reasons, they continue, the operational costs associated with HF alkylation also are lower than for H_2SO_4.

However, a review of available literature, and discussions with industry representatives, suggest that there is little, if any, cost advantage to HF alkylation units over those using H_2SO_4. With the possible exception of small plants, there are no appreciable differences in the capital or operational costs of building and operating an HF alkylation unit versus a sulfuric acid unit if all of the relevant costs are factored in.

In the past, if the refinery was located in a remote area, far from a supply of sulfuric acid, HF may have seemed like the more attractive alternative, since the spent hydrofluoric acid could be regenerated economically on site. But as previously noted, new regeneration technologies are making on-site sulfuric acid regeneration plants more fiscally attractive. At the present time, a sulfuric acid regeneration plant adds somewhere in the neighborhood of $10–$12 million to the capital cost of an H_2SO_4 alkylation unit. However, experts suggest that this figure will drop to \$5–\$7 million in the near future as these new technologies come on line. Sulfuric acid, moreover, can be regenerated with virtually no waste, whereas the average HF regeneration unit produces several hundred gallons each day of HF-laden acid tar, which must safely be disposed of by the refiner. A survey of existing refineries in the United States using on-site H_2SO_4 regeneration further suggests that such systems reduce refinery operating costs, especially in cases where the only alternative would be to transport the spent acid "some distance" to an off-site regeneration plant.

The addition of closed water systems to "knock down" fugitive HF emissions, along with other safety equipment and procedures, significantly increases the capital and operational costs associated with HF alkylation. Most sources estimate that such security measures add at least \$10–\$15 million to the cost of an HF alkylation unit, cancelling out any savings that might have been achieved in terms of the relative costs of systems to regenerate spent acid. And, such experts are quick to add, an investment at this level only buys protection from a moderate HF discharge. Such systems will not be able to neutralize a catastrophic discharge of HF. It is estimated that a refinery would have to spend in excess of \$30 million to construct a water mitigation system capable of dealing with a worst-case scenario, and even then there is no assurance that the system would be able to handle the entire fugitive HF discharge.

If environmental and safety considerations are factored into the cost equation, H_2SO_4 is far more economical than hydrofluoric alkylation. This is particularly true in the event that the plant suffers a serious or catastrophic incident, as did the Marathon facility in 1987. Although no exact figures are available, the direct and hidden costs associated with the accident are calculated to have run into the tens of millions of dollars. These included lost plant production, reduced worker productivity, claims and litigation, the loss of public confidence and good will, and calls for stronger industry regulation that were an outgrowth of Marathon's poor handling of the crisis.

Law suits have been filed following virtually every serious HF release. The widow of a refinery worker killed in the March, 1991, Southwestern Refining Company incident, for example, filed a wrongful death lawsuit against Southwestern and its parent company, Kerr-McGee Corporation.

Industrial accidents can impose devastating costs on companies. Union Carbide is expected to settle all of the claims stemming from the Bhopal, India, disaster for more than \$400 million, and the Exxon Valdez accident will cost the giant oil company in excess of \$1.2 billion in cleanup costs alone. Exxon still faces spill claims in the neighborhood of $59 billion and has seen its carefully crafted corporate image decimated by the accident and its clumsy handling of it, at least in the early stages.

It makes overwhelming economic sense for most oil companies to opt for H_2SO_4 over HF alkylation when building new plants, however conversion of existing plants is a more difficult issue. According to Mielke and Simpson, replacing the country's entire hydrofluoric acid alkylation capacity would cost $1,354,680,000.00.[49] However, as they point out, "This might be considered a maximum figure since some savings might be realized through revamping of existing equipment versus total replacement."[50]

Indeed, a substantial cost savings could be realized by converting existing HF alkylation units, rather than building entirely new facilities. Best estimates suggest that conversion of an existing HF unit to H_2SO_4 would run about 75 percent of the cost of an entirely new unit.

While conversion of HF units to H_2SO_4 would certainly not be cheap, capital costs eventually would be passed along to the consumer, and would add less than one cent a gallon to the price of gasoline. In return, the consumer could eliminate a major industrial hazard with no loss of quality at the gas pump. If adopted as a national program, conversion also would create a large number of construction and other jobs.

Recommendations

The threat of a catastrophic HF accident in the United States, or somewhere else in the world, is very real. Despite efforts to increase safety precautions and implement water mitigation systems to control errant HF discharges, such efforts will never be foolproof and, therefore, the continued use of HF alkylation poses a serious threat to public safety. Moreover, refineries, and their alkylation units, are "soft" targets for terrorists and saboteurs. Terrorists are going hi-tech, and now have the capability to threaten whole cities with their designs. The day may not be far away when they decide to strike at a refinery located in the heart of a major metropolitan area to produce a catastrophe of unparalleled proportions.

In the final analysis, then, it makes little sense to use a technology so vulnerable to accident and sabotage, particularly when a vastly safer alternative, sulfuric acid alkylation, exists. To this end the following recommendations are offered:

1. A total prohibition on the construction of new HF alkylation units in the United States.

2. A phase-out of all existing HF alkylation units in the U.S. within a decade.

3. Federally-mandated comprehensive physical security standards at all existing HF alkylation facilities to reduce the risk of sabotage.

4. Federally-mandated standards to ensure that water mitigation systems are appropriate to meet worst-case scenarios rather than some arbitrary standard set by refiners.

5. Require an Industrial Security Impact Statement regarding the siting of any new refineries in the United States, and the expansion of existing ones, with the goal of minimizing the threat from industrial accidents to adjacent populations and the susceptibility of the facility to sabotage. Such statements should be required of all industries employing potentially hazardous technologies.

6. Direct the Federal Emergency Management Agency (FEMA), working with its state counterparts, to undertake a comprehensive reassessment of preparedness, warning, and evacuation plans for responding to a major discharge of HF from all refineries utilizing HF alkylation.

7. Direct the Environmental Protection Agency (EPA) to share with other nations, both bilaterally and in international fora, information regarding the hazards associated with HF alkylation and to encourage them to explore alternative technologies.

If the above recommendations are adopted and implemented, the United States will be a safer, and more environmentally secure, place to live. Delay in addressing the hazards of hydrofluoric acid, on the other hand, will simply increase the risk of an HF catastrophe in the future.

FOOTNOTES

1. Dr. Fred Millar, statement, October 19, 1988.

2. Dr. Paul J Papanek Jr., "Medical Effects of Hydrogen Fluoride Exposure — Some Observations from the Marathon Oil Refinery HF Release, Texas City, October 30, 1987," report to Department of Health Services, County of Los Angeles, April 4, 1990, p. 2.

3. Emmett Brown, interview in "Cloud Over Texas City," ABC "20/20" report, producer: Chris Harper, September 15, 1989.

4. *Ibid*

5. *Ibid*

6 Fred Millar, quoted in "Questions Are Residue of Acid Leak," *New York Times*, December 20, 1987

7. Fred Millar, "Petrol Peril," on "Eyewitness," British Television, March, 1988.

8. According to the 1990 Clean Air Act Amendments: "Not later than 2 years after the date of enactment of the Clean Air Act Amendments of 1990, the Administrator shall, for those regions of the country which do not have comprehensive health and safety regulations with respect to hydrofluoric acid, complete a study of the potential hazards of hydrofluoric acid and the uses of hydrofluoric acid in industrial and commercial applications to public health and the environment considering a range of events including worst-case accidental releases and shall make recommendations to the Congress for the reduction of such hazards, if appropriate."

9. Appendix A, Rule 1410

10. The boiling point of sulfuric acid, by contrast, is 329 degrees Centigrade or 625 degrees Farenheit

11. *Handbook of Laboratory Safety*, p. 46.

12. *Ibid*

13. See C.F. Reinhardt, W.G. Hume, A.L. Linch, and J.M. Wetherhold, "Hydrofluoric Acid Burn Treatment," *American Industrial Hygiene Association Journal*, Vol. 27, March-April, 1966, pp. 166-171.

14. G.E. Harris, D.S. Davis, G.B. Wolf, J.D. Quass, "Control of Accidental Releases of Hydrogen Fluoride," paper presented at the Symposium on Safety in Chemical Operations, American Institute of Chemical Engineers Annual Meeting, New York City, November 15-20, 1987, p. 31.

15. *Ibid*

16. Dr. Ronald P. Koopman, testimony before the House Government Activities and Transportation Subcommittee of the Committee on Government Operations, in Los Angeles, October 19, 1987 (revised on October 22, 1987)

17. George Stein, "Mobil Refinery Explosion Laid to Human Error," *Los Angeles Times*, Feb. 11, 1990

18. Only five percent (5%) of the sulfuric acid consumed is used in petroleum alkylation.

19. James E. Mielke and Michael M. Simpson, "Refining the Refinery: Alkylation by Hydrofluoric Acid or Sulfuric Acid?," prepared for Representative Mel Levine, (Washington, D.C.: Congressional Research Service of the Library of Congress, October 24, 1989).

20. Susan Kurata and Steve Smith, "Draft Environmental Assessment for Fluoride Transportation, Storage and Use in the South Coast Air Basin," draft paper, December 20, 1989.

21. Conrad V Chester, Energy Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.; letter to Dr. Robert Kupperman, April 19, 1991, p. 1.

22. Fred Millar, press conference, November 16, 1987.

23. See D.N. Blewitt, J.F. Yohn, D L. Ermak, "An Evaluation of SLAB and DEGADIS Heavy Gas Dispersion Models Using the HF Spill Test Data," 1986.

24 Fred Millar, statement, October 19, 1988.

25. *Oil & Gas Journal,* "HF Spill Behavior and Mitigation Techniques," October 17, 1988

26. *Los Angeles Times,* "Refineries Lack Means to Handle Corrosive Acid Leaks, Report Says," May 6, 1989.

27. Some industry sources maintain that the remaining 10 percent will not hug the ground, but will tend to disperse more widely and at a higher elevation. However, more research needs to be done to confirm such assertions.

28. South Coast Air Quality Management District, "Modeling of Accidental Hydrogen Fluoride and Sulfuric Acid Releases and Comparison of Air Quality Impacts," report, p. 2.

29. *Ibid*

30 The releases were equivalent to holes 25 inches and 1.60 inches in diameter .

31. Richard W. Prugh, "The Controlled Dispersion of Liquid Spill and Vapour Emission Incidents by Water Spray," paper, June 12, 1987, p. 155

32. Conrad V Chester, letter to Dr Robert Kupperman, *op cit*

33. Fred Millar, letter from the Environmental Policy Institute to mayors, January 14, 1988.

34 Interview with author, London, July 3, 1991

35. Experts say that Western European countries can be divided into three groups according to their level of environmental awareness and activism. The first, most advanced, group comprises nations like Germany, the Netherlands, and some of the Scandanavian countries The second group, which is characterized by "some victories but still a long way to go," is said to include France, Great Britain, and Italy. The final group, composed of nations for whom economic development is the paramount goal and environmental considerations are relegated to the background, is made up of Spain, Portugal, and Greece.

36. Phillips 66 Company Woods Cross Petroleum Refinery, "Chemical Safety Audit Report," West Bountiful, Utah, (no date).

37. David Chatellier, interview, May 3, 1991.

38. *Ibid.*

39. Confidential reports prepared by U.S. security firms during the 1990–1991 Gulf crisis and war with Iraq.

40. *Ibid.*

41. *Ibid.*

42. Final report from security consultants to their client, dated March 15, 1991.

43. Like the previous scenarios, this is not a blueprint for sabotaging a refinery or bombing a train. There already is ample material — "how to" books and manuals — in the public domain on sabotage of industrial and transportation facilities. For a description of such "mayhem" literature, the reader is referred to Neil C. Livingstone, *The Cult of Counterterrorism,* (Lexington, Mass.: Lexington Books, 1990), see Chapter Five.

44. Professor Lyle F. Albright, School of Chemical Engineering, Perdue University; letter to

Richard Rosenzweig, November 3, 1989

45 The 1987 rail car derailment rate in the United States breaks down as follows. Intra-city: 959 derailments, 78 collisions, and 255 other accidents. In yards: 698 derailments, 188 collisions, and 207 other accidents. On sidings: 204 derailments, 31 collisions, and 39 other accidents.

46. David Chatellier, interview, May 3, 1991.

47. *Ibid*

48. "Do You Know Where Your Secrets Are?," *Security Intelligence Report*, April 8, 1991, p. 3.

49 Mielke and Simpson, *op. cit.*, p 11.

50 *Ibid*

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APPENDIX 1

DAILY HF ALKYLATE PRODUCTION IN THE U.S.

Major Metropolitan Areas Directly Affected:

City	*Barrels per day of HF Alkylate Produced*
New Orleans	74,900
Chicago	46,000
Houston	37,700
Philadelphia	25,500
Los Angeles	25,300
St. Louis	8,000
Cincinnati	6,000
Tulsa	6,000
Minneapolis/St. Paul	5,900
Seattle	5,900
Indianapolis	4,500
Memphis	3,600
Baton Rouge	3,500
Salt Lake City	1,000

Secondary Areas Directly Affected:

City	*Barrels per day of HF Alkylate Produced*
Corpus Christi, Texas	38,100
Port Arthur, Texas	31,900*
Wichita, Kansas	16,200
Ponca City, Oklahoma	9,700
Canton, Ohio	7,000
Billings, Montana	6,900
Duluth, Minnesota	5,900
Bismarck, North Dakota	3,000
Odessa, Texas	3,000
Cheyenne, Wyoming	2,750
Gallup, New Mexico	1,400

Areas of Greatest Potential Damage Due to HF Releases:

City	*Barrels Per Day of HF Alkylate Produced*	*# of Units*
New Orleans	74,900 bbl/day	4 HF units
Chicago	46,600 bbl/day	3 HF units
Corpus Christi	38,100 bbl/day	5 HF units
Houston	37,700 bbl/day	4 HF units
Philadelphia	25,500 bbl/day	2 HF units
Los Angeles	25,300 bbl/day	3 HF units
TOTAL	247,500 bbl/day	21 HF units

*Proposed 15m BPD HF Unit.

APPENDIX 2

U.S. HF REFINERIES

CALIFORNIA

1. Golden West Refining Company — Santa Fe Springs
2. Mobil Oil Corporation — Torrance
3. Powerine Oil Company — Santa Fe Springs
4. Ultramar, Inc. — Wilmington

ILLINOIS

5. Clark Oil & Refining Corporation — Blue Island
6. Clark Oil & Refining Corporation — Hartford
7. Marathon Petroleum Company — Robinson
8. Mobil Oil Corporation — Joliet
9. Uno-Ven Company — Lemont

INDIANA

10. Indiana Farm Bureau Cooperative Association Inc. — Mt. Vernon
11. Marathon Petroleum Company — Indianapolis

KANSAS

12. Coastal Refining and Marketing, Inc. — El Dorado
13. Coastal Refining and Marketing, Inc. — Wichita
14. Farmland Industries, Inc. — Coffeyville
15. National Cooperative Refinery Association — McPherson
16. Texaco Refining & Marketing, Inc. — El Dorado
17. Total Petroleum, Inc. — Arkansas City

KENTUCKY

18. Ashland Petroleum Company — Catlettsburg

LOUISIANA

19. BP Oil Company — Belle Chasse
20. Marathon Petroleum Company — Garyville
21. Mobile Oil Corporation — Chalmette
22. Murphy Oil USA, Inc. — Meraux
23. Placid Refining Company — Port Allen

MICHIGAN

24. Total Petroleum, Inc. — Alma

MINNESOTA

25. Ashland Petroleum Company — St. Paul Park

MONTANA

26. Cenex — Laurel
27. Conoco, Inc. — Billings
28. Exxon Company — Billings

NEW JERSEY

29. Mobil Oil Corporation — Paulsboro

NEW MEXICO

30. Giant Industries, Inc. — Gallup
31. Navajo Refining Company — Artesia

NORTH DAKOTA

32. Amoco Oil Company — Mandan

OHIO

33. Ashland Petroleum Company – Canton

OKLAHOMA

34. Conoco, Inc. – Ponca City
35. Kerr-McGee Refining Corporation – Wynnewood
36. Sun Refining and Marketing Company – Tulsa
37. Total Petroleum, Inc. – Ardmore

PENNSYLVANIA

38. BP Oil Company – Marcus Hook
39. Chevron USA, Inc. – Philadelphia

TENNESSEE

40. Mapco Petroleum, Inc. – Memphis

TEXAS

41. Amoco Oil Company – Texas City
42. Champlin Refining & Chemicals, Inc. – Corpus Christi
43. Chevron USA, Inc. – Port Arthur
44. Coastal Refining and Marketing, Inc. – Corpus Christi
45. Crown Central Petroleum Corporation – Houston
46. Diamond Shamrock Corporation – Three Rivers
47. Fina Oil & Chemical Company – Big Spring
48. Hill Petroleum Company – Houston
49. Hill Petroleum Company – Texas City
50. Howell Hydrocarbons, Inc. – San Antonio
51. Marathon Petroleum Company – Texas City
52. Phillips 66 Company – Borger
53. Phillips 66 Company – Sweeny
54. Phillips 66 Company – Odessa
55. Southwestern Refining Company, Inc. – Corpus Christi
56. Valero Refining Company – Corpus Christi

UTAH

57. Big West Oil Company – Salt Lake City
58. Chevron U.S.A. – Salt Lake City
59. Phillips 66 Company – Woods Cross

WASHINGTON

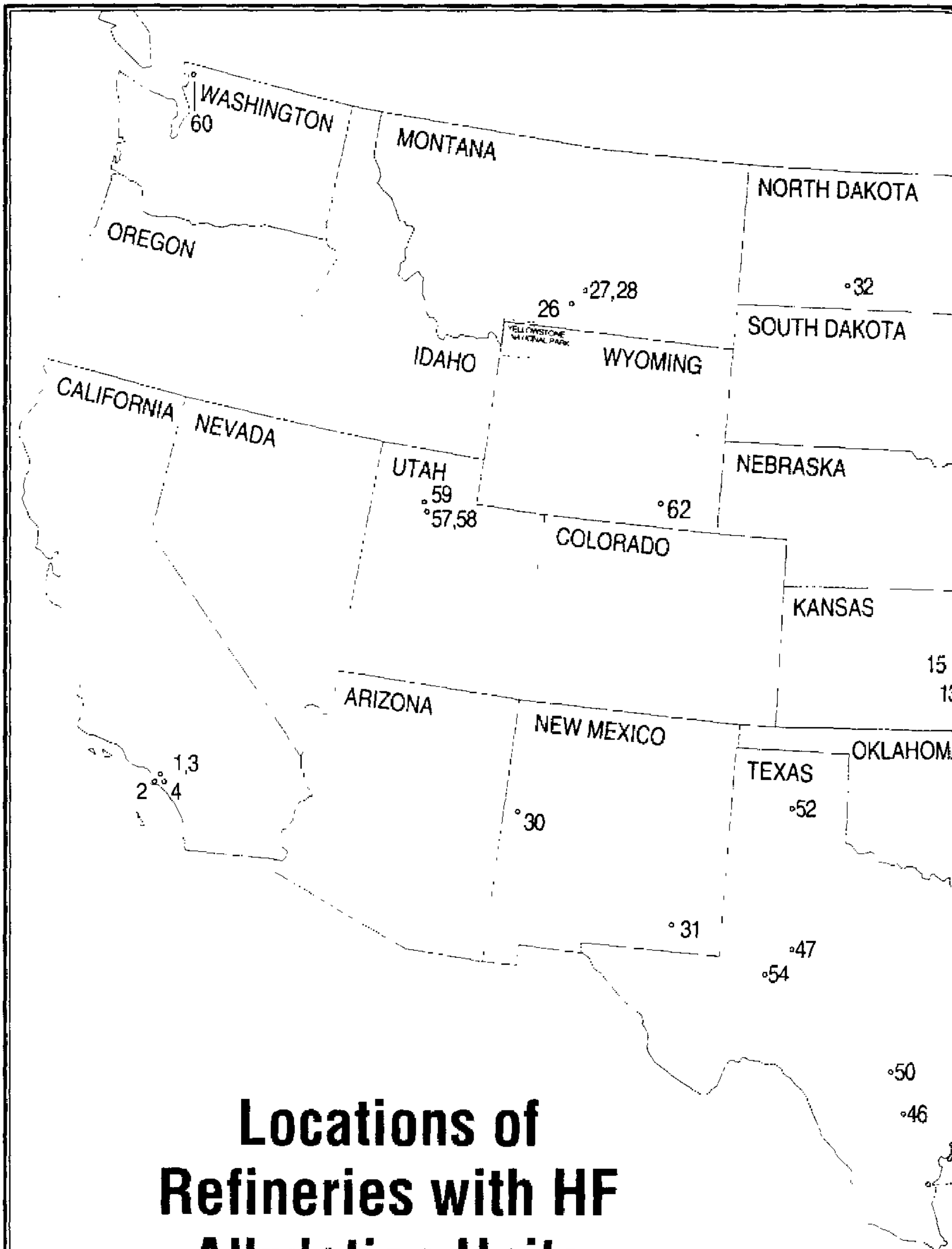
60. BP Oil Company – Ferndale

WISCONSIN

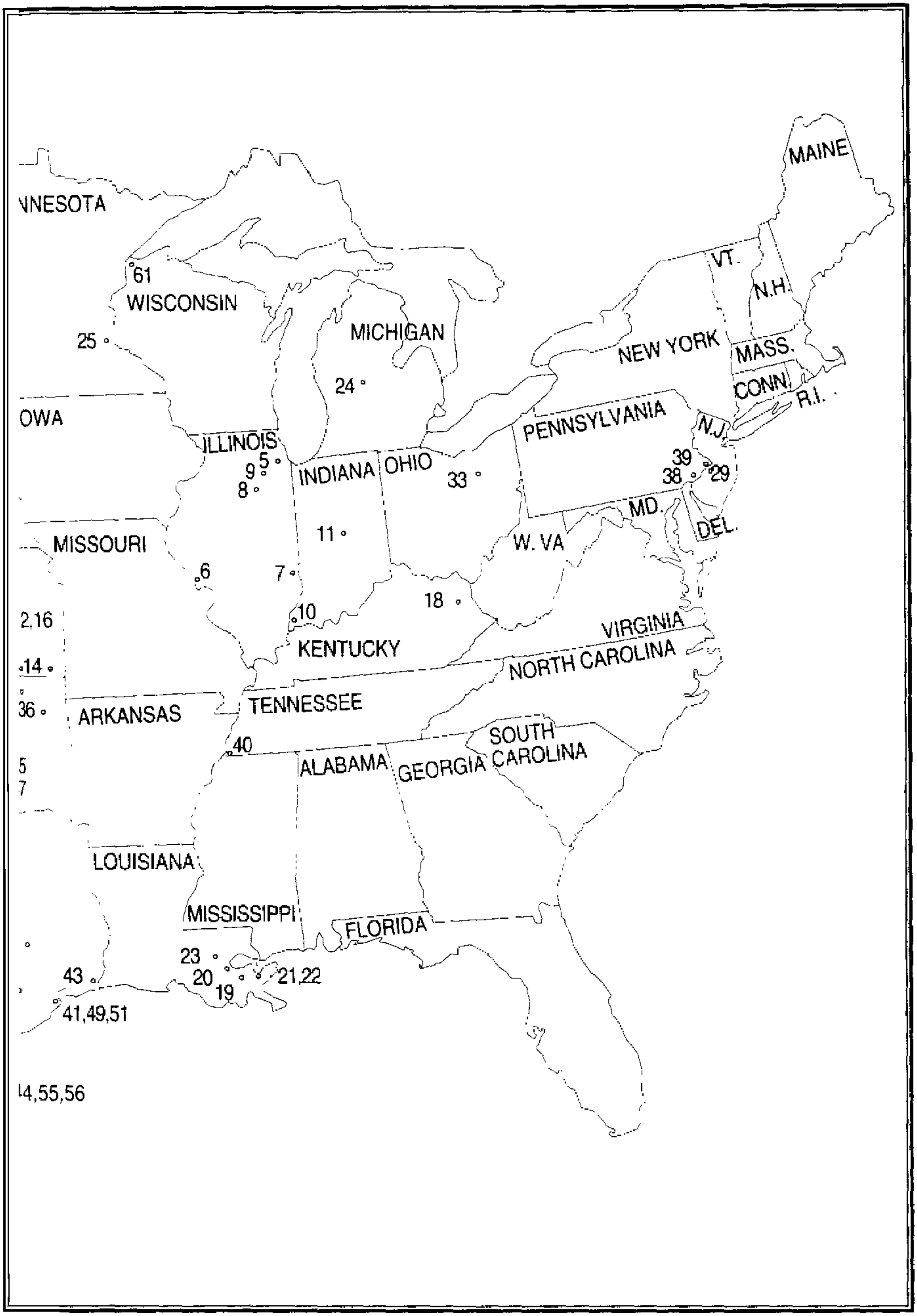
61. Murphy Oil USA, Inc. – Superior

WYOMING

62. Frontier Oil and Refining – Cheyenne



Locations of Refineries with HF Alkylation Units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APPENDIX 3

SUBNATIONAL ATTACKS AGAINST ENERGY ASSETS 1980 THROUGH MID-1989

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Afghanistan	3*		7	22	37	38	6	18	23**	6	160
Angola	1	1		3	26	17	12	4	28	7	99
Antigua & Barbuda									2		2
Argentina					1		1	4	2	1	9
Australia	1			2			1			2	6
Austria					1		3			1	5
Bahrain								1			1
Bangladesh							1	5			6
Belgium	1				4	5					10
Bolivia		8		1	2	1	1	1	2		16
Brazil				1			2	2	4	3	12
Burma				1					10	1	12
Canada	7	1	4				1		2	1	16
Chad						1					1
Chile	1	6	6	21	107	32	46	32	57	18	331
China (PRC)		1							5	2	8
Colombia	3	18	3	4	6	22	47	36	111	58	311
Congo	1										1
Corsica					1				2		3
Costa Rica				2	1	1					4
Cyprus						1					1
Czechoslovakia							1	1			2
Denmark			1				17	19			37
Djibouti									2		2
Dominica		1									1
Dominican Republic								2		1	3
Ecuador				1	3		1	1	1	1	8
Egypt		2									2
El Salvador	21	140	91	88	112	111	37	39	153	166	958
Eritrea					1		3				4
Ethiopia						1		2	5	2	10
Fiji								1			1
France	20	9	11	3	5	10	7	3	3	1	72
Greece	2		1			1	4		2	1	11
Guatemala	1	15	30	1	2	9	5		8	1	72
Guinea									1		1
Haiti							1	3			4
Honduras	1	1	5	1					3		12
Hong Kong		1									1
Hungary										1	1
India	3	3			3	2	3	14	5	4	37
Indonesia		1								1	2
Iran	24	5	2			3	1	7			42
Iraq	2		2		1	8	21	31	9		74
Ireland		1	1								2
Israel	3	2				1	3	2	4		15
Italy	5	1		1		1	2	7	6	4	27
Jamaica		2									2
Japan	1	4	2		1	1	2	1	9		21
Jordan						1					1
Kampuchea				1	19	4	18	11	4		57
Kenya			1								1
Kuwait		2		2			1	4			9
Laos									1		1

APPENDIX 3 — *continued*

SUBNATIONAL ATTACKS AGAINST ENERGY ASSETS 1980 THROUGH MID-1989

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Lebanon		2	8	1	1		3	1			16
Lesotho				2	1						3
Libya		1						1			2
Luxembourg						6					6
Malaysia							2				2
Maldives							2				2
Mexico		2			1	1	1		5	2	12
Morocco					1						1
Mozambique	3	6	9	7	15	12	9	23	33	5	122
Namibia	1	1	1	2	3	1	5	3	2		19
Netherlands	2	1				3	7	2	7	2	24
New Caledonia						1	1		2		4
Nicaragua		1	2	15	9	9	3	34	11	2	86
Niger			1	1							2
Nigeria								2	2	1	5
North Sea										2	2
Northern Ireland								3			3
Norway		1	1								2
Pakistan				4		2	6	5	9	2	28
Palestine								2	2		4
Panama				1		1		1	1	1	5
Papua New Guinea									2	7	9
Peru	2	18	35	25	21	45	49	40	64	52	351
Philippines		2			6	13	10	16	8	2	57
Poland		3					1		1	4	9
Portugal						2					2
Saudi Arabia								1	3		4
Senegal									1		1
Sierra Leone								3			3
Singapore								1			1
Somalia		1			4	4	1	2	2		14
South Africa	3	7	7	5	9	29	27	6	5	4	102
South Korea									1		1
South Yemen			2				2				4
Spain	13	34	9	2	2	1	1	3	13	5	83
Sri Lanka			1		1	4	5	4	24		39
Sudan		1		2	2	3	3	4	2		17
Suriname				2	2		4	8		1	17
Syria		1	1	1		1					4
Switzerland	3	3		3	1					1	11
Taiwan									2		2
Thailand		1							1		2
Trinidad & Tobago	1					1					2
Tunisia					1						1
Turkey	6	1	2	2	2		8	10	2	4	37
Uganda		1			3	1					5
USSR							1		5	5	11
UAE						1					1
United Kingdom	6	1			3	1	1	2	3	2	19
UNITED STATES	44	43	32	29	19	27	25	27	44	33	323
Uruguay								1			1
Venezuela										1	1
West Germany	4	4	5	1	6	29	153	7	22	2	233
Western Sahara					1	2					3

APPENDIX 3 — *continued*

SUBNATIONAL ATTACKS AGAINST ENERGY ASSETS
1980 THROUGH MID-1989

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Yugoslavia							4	3		4	11
Zaire						1					1
Zambia							1			1	2
Zimbabwe		1		2							3
TOTALS	189	362	283	262	447	472	581	466	752	429	4,243

*In many instances, the numbers of incidents are considerably understated. Many accounts do not enumerate such occurrences, but merely note that they have occurred or note that some number of targets were sabotaged during a stated period.

**Underlined numbers are new totals.

APPENDIX 4

ENERGY ASSETS AFFECTED IN SUBNATIONAL INCIDENTS: 1980 thru Mid-1989

TARGET SUMMARY

Target Type	*Number Affected*
Power pylon/powerline	8,866*
Fuel tanker truck	1,912
Service stations	784
Power substation	607
Personnel	400
Petroleum/gas pipeline	387
Central power station	366
Petroleum storage tank/storage depot	345
Corporate/government offices	170
Truck/car	108
Support facilities	86
Refinery	85
Railroad tank car	78
Mine	74
Oilwell/oilfield/oilcamp	52
Local power generator	52
Railroad	46
Construction site	29
Construction equipment	20
Industrial power plant	18
Helicopter/fixed wing aircraft	16
Pipeline pumping station	16
NG/LPG "facility"	15
Deep sea vessel/lighter	14
Offshore platform	13
Spent nuclear fuel	9
Barge	8
Nuclear waste	8
Train	4
Petroleum terminal	4
Computer data files/networks**	1
TOTAL	14,593

*Underlined numbers are new totals

**New category

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