# *A History of Engine Defeat Through Chemical Means*

**Kenneth R. Collins**
**Donald R. Bowie**

# Origin and Early History

Edgewood Chemical Biological Center

**"On the day of the race both the gasoline and the lubricating oil are kept guarded to prevent trickery in the way of adding water, which would soon put the car out of commission".**

***Leslie's Illustrated Weekly (Oct 4, 1906)***

**from a description of auto racing in its infancy**

Picture of 1922 Edgewood Arsenal Anti-Tank Gas Test

# Origin and Early History - II



**"The Chemical Warfare Service is in frequent receipt of suggestions . . . Concerning the possible use of chemicals in the air for the purpose of interfering with the operation of gasoline motors. . . There are even some records of suggestions. . . Having been made during the course of the [First] World War."**

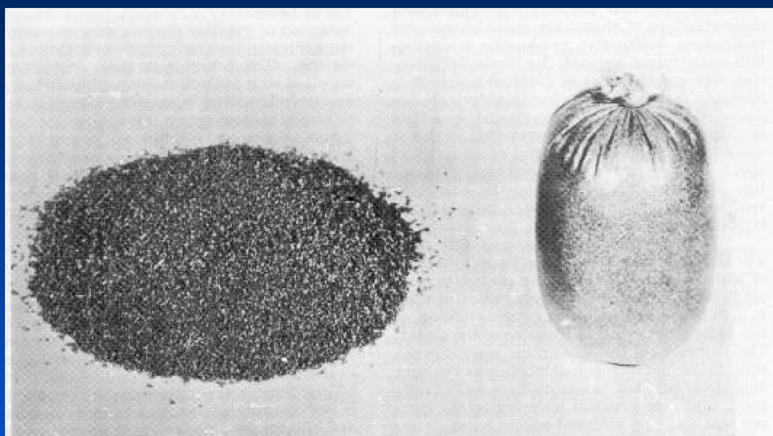
*Maj M.E. Barker, CWS*
*(July 13, 1939)*

# Picture of Beacon Labs
# WWII ‘Proknock’ Test Facility

*POL Contamination -*

# Production Highlights - Caccolube

Edgewood Chemical Biological Center



**Item and Content**
**(total wt 2 oz)**

**“ Caccolube is reported to be one of the most popular items in the OSS catalog.”**

**W.C. Lothrop (OSS R&D)**
**14 Feb 1945**


**Instruction Card**

# Production Highlights - Firefly Device

# Scan of Fieser's Biography Showing Napalm Pellets as POL Contaminants

# Sugar – Fact or Fiction?

Edgewood Chemical Biological Center

*** Upper limits for solubility of sucrose in gasoline using C14 labeled sugar - 1.5 mg/liter (ca 2 ppm)**

*J. Forensic Sciences **38**, pg 757 (July 93) & **39** pp 303-4 (Mar 94).*

*** ASTM D-381 gum results - SwRI Unpublished Data**

| | Neat Fuel | Granulated Sugar | Powdered Sugar | Brown Sugar |
|---|---|---|---|---|
| Diesel DF-2 | 10.3 | 8.5 | 5.7 | 5.6 |
| Jet A | 0.5 | 1.0 | 0.7 | 0.7 |
| JP-4 | 0.6 | 0.3 | 0.4 | 3.2 |
| Unleaded Gasoline | 1.2 | 1.0 | 0.2 | 1.6 |

10 g of sugar added to 1 liter of fuel, stirred for 24 hours

***"A large amount of sugar could stop fuel flow in many systems but so could plain dust swept from the ground."***

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Kenneth R. Collins
Donald R. Bowie
US Army Edgewood Chemical Biological Center
Aberdeen Proving Ground, Maryland

One of the more interesting aspects of nonlethal warfare considers the possibility of the defeat of engines without causing extensive damage to their surroundings or operating personnel. Since an internal combustion engine is dependent on a continuous supply of fuel and air, these items represent two main avenues of nonlethal engine disablement. In fact, recent media coverage of the military interest in nonlethal weapon development contains many references to these possibilities[(1-3)]. Despite the impression from such coverage that these concepts are new and novel, the military has long considered the value of these technologies. In this paper a brief historical overview of some of the early development in this area is presented.

The potential for chemical mischief from intentional fuel contamination was recognized soon after the introduction of engine driven vehicles. For example, consider the following quote from a 1906 account of early auto racing[(4)]:

*"On the day of the race, both the gasoline and the lubricating oil are kept in tanks, which are sealed and guarded to prevent trickery in the way of adding water, which would soon put the car out of commission."*

First hand experience with airborne contamination adversely affecting engine operation was first noticed by the military during World War I. The tank drivers noted that problems with engine operation would arise as they drove their tanks into areas recently suffering from a gas attack. Specifically, as the chlorine settled into the depressions of the terrain, air-breathing engines would stall as it ingested the heavy gas. Furthermore, the corrosive nature of the gas was also suspected of having a deleterious effect on the exposed machinery of the tank engine. Concerns such as these lead to a series of field tests at Edgewood Arsenal in 1923, employing a 6-ton gasoline driven tank operating within chlorine gas clouds[(5)]. After 171 minutes of exposure, the motor was observed to stop, and could not be started back up again.

The 1920's and 1930's also marked the discovery of fuel additives capable of both improving and degrading the performance of gasoline. It was during this period that Thomas Midgely discovered the performance enhancing capability of the addition of tetraethyl lead to gasoline, expressed in the now familiar terms of a Research Octane Number (RON) boost. A number of laboratory studies also reported on a wide range of additives that markedly lowered the measured RON, causing severe knock during engine operation[(6-8)].

The military, chiefly through Edgewood Arsenal, kept abreast of developments throughout these decades. The effects of chemicals on the battlefield against personnel were well documented by this time - extrapolation of chemical operations against enemy materiel was an obvious extension. One of the more important antimateriel chemical technologies considered at this time involved interference with the operation of vehicles. Quoting from a 1939 memorandum for record by MAJ M.E. Barker of Edgewood Arsenal(9):

*"The Chemical Warfare Service is in frequent receipt of suggestions . . . concerning the possible use of chemicals in the air for the purpose of interfering with the operation of gasoline motors. . . There are even some records of suggestions. . . having been made during the course of the [First] World War."*

Despite the interest of the 20's and 30's, a significant development program in this area did not arise until the eve of World War II. By 1940, the CWS entered into a contract with Pure Oil Company for one dollar, with a purpose of developing an intentional gasoline contaminant that could be used on friendly supplies that would be abandoned to the advancing enemy. Supplies of Paradura 10-P (code named "Hennite"), a phenolic resin, were stockpiled, as it was found useful for this purpose when added to gasoline at about 0.25% to 1% by weight (2500 - 10,000 ppm). The search for an effective sabotage agent for friendly fuels was continued in 1941 by the National Defense Research Committee (NDRC), under contract with Monsanto Chemical Corp. During this effort, 556 tests were run on operating gasoline engines (mostly one cylinder Delco type), using over 225 compounds(10).

By 1942, the interest in fuel contamination had shifted from defensive to offensive purposes, in order to assist the Office of Strategic Services. Under the 'Caccolube' (literally, 'bad lubricant') program, the Texas Company found a constituent of flash powder that had remarkable results against engine bearings when introduced as a lubrication impurity(11). By 1944, procurement for 30,000 'turtle eggs' was completed, based on this contaminant. Additionally, Standard Oil developed the 'Firefly' device, a hand held explosive incendiary triggered by immersion in fuel. By late 1944, a total of 98,000 small sized models were procured; by late 1945, these were augmented with 500 additional larger versions. Many additional fuel and lubricant additives were provided for operational employment during World War II, most notably the 'napalm clots' as described by Louis Fieser(12).

Ingestion of airborne vapor clouds was also pursued in earnest starting around the eve of World War II. In January of 1938, the Standard Oil Company reported that carbon tetrachloride used in the vicinity of running engines produced detonation in the engine's operation. After a series of subsequent tests to optimize this effect using other halogenated organic materials, the company offered the information to the Chemical Warfare Service. A development project was started on this concept, focussing on the possibility of use of this technology as an anti-aircraft type weapon. As World War II began, this work lead to the development of the NDRC's 'Project Pro-knock' (CWS project No. 5)[10]. Although Ethyl Gasoline Company was the prime contractor for this effort, a number of military and other contractor sites were also heavily involved until the project closed down in 1943. Approximately 250 materials were tested in varying concentrations using a wide range of fuel types. As an interesting sidebar, the NDRC chairman assigned to this project was Thomas Midgley, now being asked to 'reverse engineer' all the benefits to gasoline RON that he provided with the discovery of tetraethyl lead additive earlier in his career.

In 1951, Robert Kracke from the Army Chemical Center at Edgewood Arsenal, studied both the vapor ingestion[13] and fuel additive[14] methods of engine defeat. Although his investigations were severely constrained by predefined military requirements, both of these excellent studies can serve as primers for any future work.

In the former program, Kracke and his coworkers studied solids, liquids and gases of all types, from Cement Dust to Nitromethane, to Chlorine Trifluoride. He also employed a variety of engines, both gasoline and diesel, including electrical generators. Although he performed many successful tests, the military criteria were very stringent and his conclusion was "the discovery of a material . . . does not appear promising"

In the latter effort, Kracke evaluated a large number of compounds for their effectiveness as fuel defeat agents. Starting with the World War II work on gum formers such as Paradura, and extending the investigations to diesel fuel, he tried many classes of compounds, including organic and inorganic halogens, pure organics, nitro-compounds, and many others. The work was hampered by the fact that any additive, in order to be considered successful, was required to:

1. "Be effective in all types of gasoline and diesel fuels at a maximum concentration of 0.1% by weight" (1000 ppm).

2. "Cause major damage to all reciprocating-piston internal-combustion engines . . . requiring a complete overhaul".

Plus an additional 7 requirements that constituted a veritable 'wish list' that was impossible to fulfill. Even though they found new materials that would work at the lower level in either gasoline or diesel fuel, no material would work in both. In addition, many of the new materials were found to be toxic and/or produced strong coloration in fuels. As a result, he was forced to conclude "No agent has been found which meets the military characteristics".

After the Kracke project, development efforts in this field continued sporadically until the 1970's. Then in 1976, the Army Fuels and Lubricants

Research Laboratory at Southwest Research Institute published a study that considered over fifty chemicals "as potential combustion modifiers and/or lubricant degradants" in both gasoline and diesel engines(15) . A number of bench and field tests proved the apparent potential for widespread application of gaseous chemical interferants dispersed into the air to reliably stall air-breathing engines. This report seemed to catch the imagination of the general public - soon after its publication, a number of suggestions attempting to prod the military into additional explorations appeared in the open media(16-18). As the current interest in non-lethal weapons development first began to appear in the late 1980's, the popular press articles of the previous decade provided some of the early discussion points for potential technologies that could support a non-lethal weapons development program. Unfortunately, much of the history that has gone before the current interest in this topic has remained largely unknown to many of its current proponents.

Although this body of knowledge is now generally forgotten, its value should be readily apparent to those who wish to benefit from the prior lessons learned in the area. Also, this paper is just one example of the relevance that prior military research has in the field of non-lethal weapon development. Despite common perceptions, nonlethal technologies are concepts that are not always new to military research centers. A careful exploration of the appropriate archives can yield a wealth of valuable information to build a program upon.

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