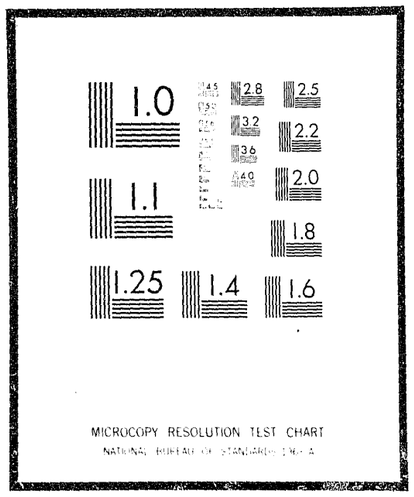

Evaluation of an Organic Acid Detector for the Detection of Heroin

Fully supported by the Law Enforcement Assistance Administration
Interagency Agreement No. LEAA-J-IAA-008-73.

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CONTENTS

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ABSTRACT

This project consisted of (1) identification of the chemical compounds that appear in significant concentrations as volatiles from heroin samples, and (2) evaluation of a specific instrument designed to detect concealed heroin by sensing these volatiles.

Volatiles detected, in approximate order of concentration, are water, acetic acid, acetone, hydrogen chloride, chloroform, methanol, ethanol, isopropanol, methylene chloride, and diethyl ether. The heroin molecule itself is not detected in the vapor phase at normal temperatures.

The instrument, based on the "Biosensor" system of the RPC Corporation, El Segundo, California, was found to respond with great sensitivity (at approximately 50 parts per billion) to acetic acid; however, its responses are not specific to acetic acid. Other low-molecular-weight organic acids are easily detected, and several types of organic and inorganic compounds elicit responses. The detector's sensitivity is a function of the background concentration of compounds that cause a response from the bacterial cultures used. The detector did not respond to pure, dry heroin; therefore, it must be considered primarily an acetic acid detector.

It is recommended that consideration of acetic acid detectors for heroin location be continued only if it is judged that sensing such a common substance is useful for this purpose.

Additional research to develop improved acetic acid detectors cannot be recommended, because instruments of adequate sensitivity and specificity are commercially available.

I. GENERAL

In response to a request from the U. S. Department of Justice, Law Enforcement Assistance Administration (Inter-Agency Agreement No. LEAA-J-IAA-008-73 between the Law Enforcement Assistance Administration and the U. S. Atomic Energy Commission, dated 13 September 1972), the USAEC undertook at its Los Alamos Scientific Laboratory (LASL) a project to evaluate a device designed to detect heroin by observing the effects of vapors from heroin samples on bioluminescent bacteria. The project was conducted over a three-month period and consisted of the following phases:

a) Analysis of four samples of heroin, supplied by the Bureau of Narcotics and Dangerous Drugs and the city of New York, to identify the volatile products and impurities.

b) Evaluation of a specific instrument designed to detect heroin by responding to volatiles from heroin samples.

c) Determination of the instrument's sensitivity to these volatiles.

d) Determination of the instrument's response to other common compounds not normally associated with heroin.

e) Determination of the instrument's response to changes in temperature and humidity.

f) Field trials to determine the feasibility of using the instrument to locate heroin in normal types of buildings.

The type of instrument evaluated utilizes a colony of luminescent bacteria as its sensitive element. Air, which may contain impurities, is drawn through a tubular probe into a volume containing the bacterial colony. Active compounds entering this volume increase or decrease the metabolic rate of the bacteria, causing the intensity of the light they emit to change accordingly. This light falls on a photoelectric sensor that provides an electrical signal whose voltage depends on light intensity. Electronic circuits in the instrument produce a meter reading when the light deviates from its previously established steady-state value. If the deviation is larger than a predetermined amount, an audio and/or visual signal is produced.

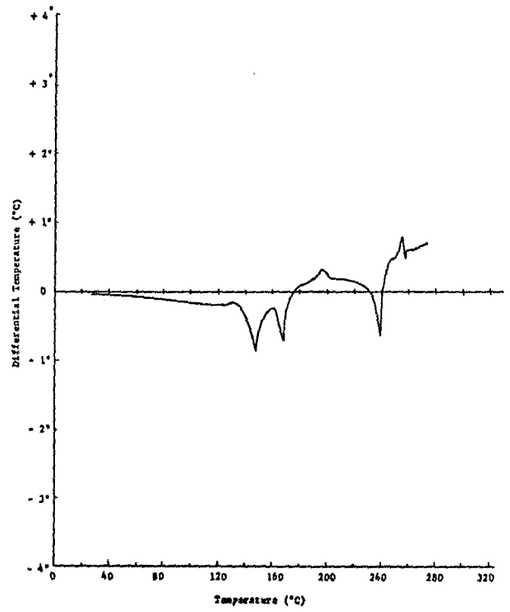

Fig. 1. DTA curve from a 10-mg sample of NYCPD heroin.

II. ANALYSIS OF VOLATILES FROM HEROIN SAMPLES

A. Thermochemical Study

Thermochemical methods were used to determine heroin's stability and the relative rates of evolution of volatiles from heroin as a function of temperature. Representative differential thermal analysis (DTA) and pyrolysis (effluent-gas analysis) curves are shown in Figs 1 and 2. The first observable reaction in the DTA curve starts at approximately 130°C. The pyrolysis curve shows that small amounts of volatiles are evolved between room temperature and 100°C; however, both curves show no appreciable thermal decomposition below approximately 200°C. The most important observation is that there is no "threshold" temperature for any of the volatiles within the normal temperature range. No sharp desolvations or decompositions need be considered at normal room temperatures, so maximum and minimum operating temperatures for a detector will depend on its sensitivity only.

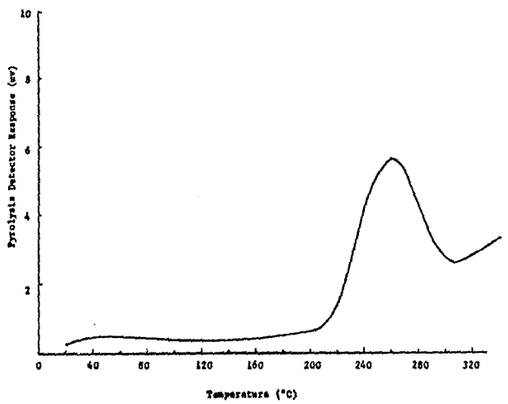

Fig. 2. Pyrolysis curve (gas-evolution rate vs temperature) from 10-mg sample of NYCPD heroin.

B. Identifiable Volatile Products and Impurities

The volatiles produced by four different heroin samples were analyzed to determine both their identities and sample-to-sample variations. The samples were: 1) a 607-g sample of brown heroin of unknown origin supplied by the New York City Police Department (NYCPD), 2) a 0.9-g sample of brown Mexican heroin cut with 60 wt % procaine and milk sugar, 3) a 100-mg sample of high-purity "Far Eastern" heroin, and 4) a 100-mg sample of "pure" heroin supplied by the Bureau of Narcotics and Dangerous Drugs (BNDD). Mass spectrometry with two mass spectrometers, gas chromatography, and two kinds of pyrolysis and gas chromatography were used for the analyses. However, only the NYCPD sample was large enough for analysis by all of these methods.

Volatiles were purged from 1-g samples of NYCPD heroin by a stream of dry nitrogen and were collected in a cold trap at - 77°C. At room temperature, approximately 2 h was required to collect a large enough sample for analysis, but enough could be collected in 15 min at 100°C. There were no appreciable differences between samples collected at room temperature and 100°C, in agreement with the results of the thermal tests.

Collected samples were analyzed by both gas chromatography and mass spectrometry. The chromatograph used was an Aerograph A-600-C, fitted with a 6-ft by 1/8-in. Poropak Q column, programmed between 120 and 150°C. Figure 3 shows representative gas-chromatographic results. Water was by far the most important volatile, followed by acetic acid, acetone, hydrogen chloride, and chloroform. Traces of methanol, ethanol, and an unidentified component were also found. When especially large volatile samples were collected, very small amounts of isopropanol, methylene chloride, and diethyl ether were detected. Methylene chloride is a common impurity in practical-grade chloroform. The same major components, acetic acid, acetone, and chloroform, were detected by mass spectrometry of the collected samples using a CEC 21-110 high-resolution spectrometer.

A 2-g sample of the NYCPD heroin was allowed to equilibrate with the air above it overnight in a sealed 10-ml ampoule at 72°F. The sample was then introduced directly into a CEC 21-103 mass spectrometer. The spectrum showed a large amount of water

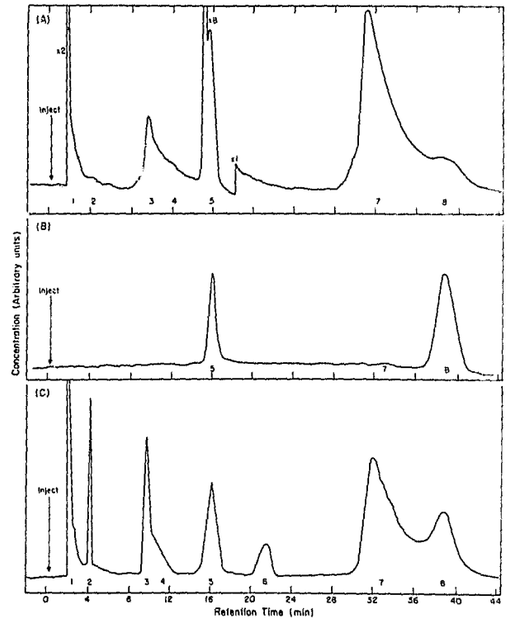

Fig. 3. Gas chromatograms of concentrated NYCPD heroin volatiles.

(A) 8-µl sample of liquid condensate of the volatiles.
(B) 2-ml sample of vapor phase above (A).
(C) 3-µl sample of standard solvent composed of equal volumes of (2) methanol, (3) ethanol, (4) HCl, (5) acetone, (6) isopropanol, (7) acetic acid, and (8) chloroform. The peak labeled (1) is the injection air peak.

and much smaller amounts of acetic acid, acetone, ethanol, methanol, and hydrogen chloride. The ampoule was sampled repeatedly, allowing different times for equilibration. All of the minor components decreased relative to acetic acid during successive samplings. A representative mass spectrum is shown in Fig. 4.

Mass spectra from all four of the heroin samples were taken by introducing the solid directly into the CEC 21-110 high-resolution spectrometer. Figure 5 shows the high-mass part of the spectra. This is not an ideal method for quantitative analysis, because much of the most volatile sample fractions is lost during introduction; however, it is the only available method for comparing small samples. During each run, the sample was heated slowly to 165°C while

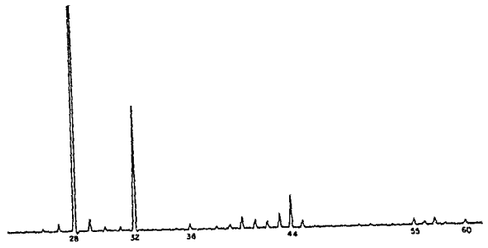

Fig. 4. Representative mass spectrum of NYCPD heroin head gases at room temperature. Some of the compounds showing detectable mass peaks are nitrogen (air) (28), methanol and ethanol (31, 45, 46), oxygen (air) (32), hydrochloric acid (36, 38), acetone (43, 58), carbon dioxide (44), and acetic acid (60).

in position in the source. The samples (except for the Mexican heroin) volatilized rapidly and completely above 140°C in the high vacuum of the spectrometer. A dark brown residue remained after analysis of the Mexican heroin. The only appreciable difference among the four samples revealed by this method was the appearance of procaine in the Mexican material. A weak line at mass 446, as yet unassigned, appeared in the spectrum of the Mexican heroin between 100 and 120°C.

In summary, volatiles obtained within the normal room-temperature range, in order of decreasing concentration, were water, acetic acid, acetone, hydrogen chloride, chloroform, methanol, ethanol, isopropanol, methylene chloride, and diethyl ether.

III. SPECIFIC DETECTOR INSTRUMENTATION

A. General Description

Three detectors for evaluation were delivered by Rodney Kemp and R. R. Sakaida of the RPC Corporation. Kemp and Sakaida prepared the required cultures and operated the detectors for the first three days to eliminate any errors that might be caused by operators unfamiliar with the equipment.

The detectors, all developed by the RPC Corporation, were: the portable, single-channel NYCPD model (similar to RPC Model 4532) that was the primary object of the evaluation (Fig. 6); a non-portable dual-channel model (RPC Model 1332-16) that uses two different bioluminescent bacterial cultures; and a hand-held, single-channel model (RPC Model 2032-14). Testing began on October 30, 1972.

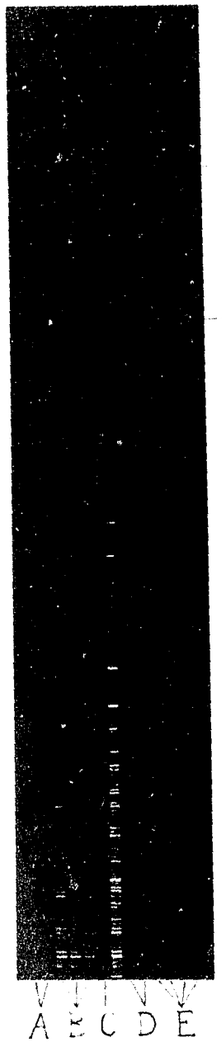

Fig. 5. Reproduction of a high-resolution mass spectrum photoplate. The spectra of all four heroin samples from a heated probe are shown with that of perfluorokerosine, mass-scale-calibration compound. (A) brown heroin from the NYCPD, (B) Mexican heroin, (C) perfluorokerosine, (D) "Far Eastern" heroin, and (E) pure heroin from the BNDD.

Intense lines at 369, 327, and 268 mass units are three prominent lines in the heroin spectrum, the nominal molecular weight being 369. Intense lines at 120, 99, and 86 mass units show the presence of procaine in the Mexican sample. Considerable detail is lost in the reduction and image-reversal process used for reproduction, and the 12 to 82 mass range has been deleted.

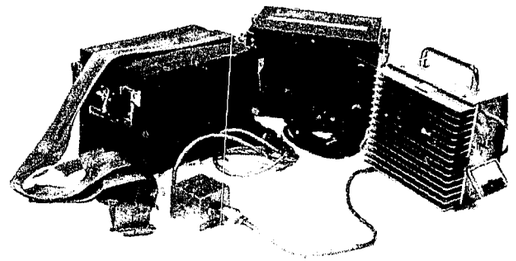

Fig. 6. The New York City Police Department heroin detector. Shown (l-r) are the battery pack, battery charging unit, and detector module. The probe is the thin, pointed member extending from the upper left of the detector module; the bacterial culture is placed in the circular compartment in the detector module. There is a center zero on the meter; deflections to the left and right indicate decreased and increased luminescence, respectively.

B. Preparation of Bacterial Cultures

Bacterial cultures were inoculated, propagated, and stored as specified by consultants from the RPC Corporation. The RPC system was modified only in that inoculations were performed in a laminar-flow hood to prevent contamination. Growth was always sufficient within the specified 16- to 18-h incubation times to provide agar plates that yielded adequate signals. All plates used in testing were incubated as recommended, but a few were tested for growth using inocula that had exceeded the suggested time limits for storage at 4°C. From these, we conclude that RPC estimates for inoculum stability are conservative, and their system has, in fact, a longer useful shelf life than is indicated in their protocols. No contaminations were encountered, and no attempts were made to contaminate the cultures. We can state only that bacterial cultures supplied by RPC and prepared according to their directions provide adequate bioluminescent intensity to operate the sensor. Attempts to compromise the cultures by changing culture conditions or to exert genetic-selection pressures were considered beyond the scope of this evaluation.

C. Electronic and Mechanical Design

As requested in the interagency agreement (paragraph 7, page 3), the circuitry and general mechanical construction of the NYCPD detector were inspected. However, this instrument was not a production model but was intended to be a feasibility and demonstration unit. No manual or circuit diagram was provided.

The NYCPD detector was adequate for its purpose: operation by skilled personnel in research or testing activities where access to repair service is available. The circuitry was more complicated than necessary to accomplish the desired electronic functions, a situation typical of such developmental devices. More sophisticated instruments appear to be available from the manufacturer, but none of the newer models were available for electronic and mechanical study.

There seem to be no special requirements of power supply, circuitry, or packaging that would make a production model unusually costly or unreliable, compared with other electronic instruments in the same general category.

IV. EXPERIMENTAL EVALUATION OF DETECTORS

A. Laboratory Tests

The dual-channel detector uses one bacterial culture that gives a positive signal (increasing luminescence) and another culture that gives a negative signal in the presence of acetic acid. The same type of positive culture was used in all of the detectors evaluated. Therefore, recorders were attached to each channel of the dual-channel model, and it was used for most of the laboratory testing. Figure 7 shows responses obtained from some representative materials.

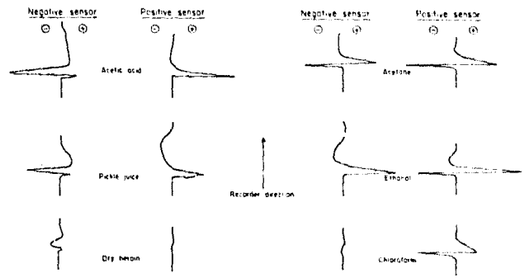

Fig. 7. Typical detector response curves of the RPC Model 1332-16, dual-channel heroin detector.

The type (positive or negative) and rate of response shown by the bacterial cultures varied from one test material to another, but nearly every compound or material presented to the detector elicited some type of response. The detector usually responded almost identically to all members of any specific class of compounds. Sensitivities and response rates of different preparations of the bacterial cultures differed, and the sensitivity and response rate of a specific culture varied with time and with changes in temperature, humidity, and environment. The response to dry heroin is identical to that obtained by inserting the detector probe into a desiccator.

Many different chemical compounds and materials were surveyed to identify the types of response that might be expected. Most were common chemicals of different classes. Some were solvents used in heroin production or found in common heroin-cutting agents. All of the volatiles detected over heroin samples were included in the tests.

The dual-channel detector was designed to sound its alarm when the initial response of the positive sensor was positive (+) and that of the negative sensor was negative (-); however, rate and "rebound" problems could cause false alarms. The initial response of one or both channels was often in the wrong direction to cause an alarm, but when the detector recovered the signal would cross its original zero position (rebound) to cause an alarm. An excellent example of this type of behavior is the ethanol curve in Fig. 7. Study of the recorder traces, careful observation of the detector meter, or suitable redesign of the electronics to include signal logic would largely obviate this problem.

The negative culture was found to change characteristics more rapidly than did the positive culture. When subjected to almost any major external change, it suffered an irreversible loss in sensitivity and response rate. The properties of the negative culture made the dual-channel detector appreciably more difficult to use than the single-channel detectors.

The NYCPD detector will give an alarm for any response, either initial or rebound, in the positive direction; however, it is relatively simple to detect rebound responses in the single-channel detectors.

Responses obtained with the RPC dual-channel detector are presented in Table I, and those obtained with the NYCPD single-channel detector are shown in Table II.

TABLE I. RESPONSES OBTAINED WITH THE RPC DUAL-CHANNEL DETECTOR.

Compound	Detector Response Pattern: Positive Sensor	Negative Sensor	Remarks
Acids			
Formic Acid (40% soln)	+, -, +	+, -	Alarm
Acetic Acid*	+, -	+, -	Alarm
Propionic Acid	+	+, -	Alarm
Butyric Acid	+	+, -	Alarm
Oleic Acid	+	+	No alarm
Stearic Acid	None	None	No alarm
Benzoic Acid	None	None	No alarm
Mercapto Acetic Acid	+	-	Alarm
Hydrogen Chloride (12N)	+	+, -	Alarm
Hydrogen Chloride (~ 0.1N)	+, -	+	No alarm
Alcohols			
Methanol*	-, +	-, +	Alarm
Ethanol*	-, +	-	No alarm
Isopropanol*	-, +	-, +	Alarm
Allyl Alcohol	-, +	+, -	No alarm
Amyl Alcohol	+, -	-	Alarm
Ketones			
Acetone*	-, +	-, +	No alarm
Methyl Isobutyl Ketone	-, +	-, +	Alarm
Aldehydes			
Formaldehyde (soln)	+, -	+	No alarm
Acetaldehyde	-, +	+, -	Alarm
n-Butyraldehyde	-, +	-, +	No alarm
Saturated Hydrocarbons			
Pentane (practical)	-, +	None	No alarm
Petroleum Ether	-, +	None	No alarm
Unsaturated Hydrocarbons			
2-Pentene (practical)	-, +	-	Alarm
4-Methyl-1-Pentene	-, +	-	Alarm
1,5-Hexadiene	-, +, -	-, +	Alarm
Amines			
n-Propylamine	-	-	No alarm
Di-n-Butylamine	-, +	-, +	No alarm
Triethylamine	-, +	-, +	No alarm
Halogenated Hydrocarbons			
Methylene Chloride*	-, +	None	No alarm
Chloroform*	-, +	None	No alarm
Carbon Tetrachloride	-, +	None	No alarm
Methyl Chloroform	-, +	-	Alarm
Anhydrides			
Acetic Anhydride	+, -, +	+, -	Alarm
Ethers			
Diethyl Ether*	-, +	-, +	Alarm
Aromatics			
Benzene	-, +	-	Alarm
Anthracene	None	None	No alarm
Phenol	-, +	-	No alarm
Aniline	-, +	None	No alarm
Miscellaneous			
Heroin	+	-	Alarm
Desiccated Heroin	-	-	No alarm
Magnesium Perchlorate	-	-	No alarm
Ethyl Acetate	-, +	-, +	Alarm
Camphor	-, +	-	Alarm
Potato Starch	+, -	+, -	No alarm
Mannitol	+, -	+, -	No alarm
B-Lactose	+	+, -	No alarm
Tap Water	+, -	+	No alarm
Whiskey	-, +, -	+	No alarm
Pickle Juice	+, -	+, -	Alarm
Wet Mustard	+	+, -	Alarm
Vinegar	+	+, -	Alarm
Catsup	+	+, -	Alarm
Ground Coffee	+, -	+, -	Alarm
Root Beer	+, +, -	+, -	Alarm
Grape Juice	+, -	+, -	Alarm

*Detected from the NYCPD heroin sample.

TABLE II. RESPONSES OBTAINED WITH THE RPC SINGLE-CHANNEL, PORTABLE, NYCPD DETECTOR.

Compound	Detector Response Pattern: Positive Sensor	Remarks
Acids		
Formic Acid	+	Alarm
Acetic Acid	+	Alarm
Propionic Acid	+	Alarm
Butyric Acid	+	Alarm
Ketones		
Acetone	-, +	Alarm
Methyl Isobutyl Ketone	None	No alarm
Aldehydes		
Formaldehyde (sol'n)	+	Alarm
Acetaldehyde	+, -	Alarm
Alcohols		
Methanol	-, +, -	Alarm
Isopropanol	-, +	Alarm
Ethers		
Diethyl Ether	-	No alarm
Saturated Hydrocarbons		
Pentane (practical)	None	No alarm
Halogenated Hydrocarbons		
Chloroform	-, +	Alarm
Aromatics		
Benzene	-, +	Alarm
Phenol	-	No alarm
Unsaturated Hydrocarbons		
2-Pentene	-	No alarm
1,5-Hexadiene	-	No alarm
Amines		
Isopropylamine	-	No alarm
Miscellaneous		
Heroin	+, -	Alarm
Root Beer	+	Alarm
Coca Cola	+	Alarm
Wet Mustard	+	Alarm
Catsup	+	Alarm
Cigar Smoke	+	Alarm

The survey tests summarized in Tables I and II were designed to allow observation of a detector response at any attainable concentration of the test substance in air, with no attempt to control concentrations. To test detector sensitivity, known concentrations of representative compounds were produced in a sealed environmental test chamber with a volume of 16 m^3 (Fig. 8). The results of these tests are shown in Table III.

The sensitivity testing revealed some differences among the three detectors. The hand-held model seemed more sensitive and rapid than the other two, probably because it had a better air pump. The NYCPD model was slightly more sensitive than the dual-channel model. All showed the same variations in sensitivity and stability with changes in cultures and conditions.

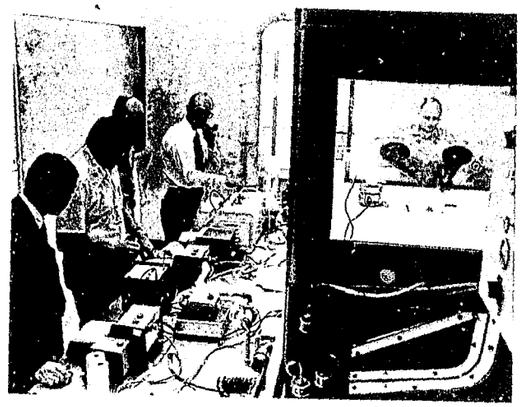

Fig. 8. The environmental test chamber used for detector-sensitivity determinations, showing a simulated cutting operation in progress. The RPC dual-channel detector, Model 1332-16, is shown in the foreground.

TABLE III. DETECTOR SENSITIVITY TESTS.

Compound	Concentration	Comments
Formic Acid (sol'n)	35 ppb	No response
	100 ppb	No response
	10 ppm	Alarm
Acetic Acid	10 ppb	No response
	30 ppb	No response
	60 ppb	Alarm
	100 ppb	Alarm
Propionic Acid	1 ppm	Alarm
Acetone	1 ppm	No response
	10 ppm	No response
Methanol	2000 ppm	No response
Ethyl Acetate	10 ppm	No response
Triethylamine	1 ppm	No response
N-Butyraldehyde	1 ppm	No response
	10 ppm	No response
Open Catsup Bottle		Alarm in 2 min
Simulated Heroin Cutting[a]		Alarm in 10 min
Open Mustard Bottle		Alarm in 15 min

[a]The relative humidity during these tests was ~ 20% at 25°C. At higher humidities and temperatures, the response was considerably faster.

B. Field Tests

Field testing was required to evaluate the practical consequences of the laboratory observations. It was desirable to subject the detector to atmospheres resulting from a wide range of human activities, so arrangements were made to test the NYCPD detector at the local high school, a local motor hotel, and in private homes. The high school is relatively congested during class hours, and it includes a wide variety of facilities, laboratories, business offices, gymnasiums, locker rooms, public restrooms, classrooms, a teachers' lounge, and a cafeteria. While we were testing the detector at the high school, we were fortunate to find a class party and a cooking demonstration in progress. We arranged to test the detector at the motor hotel while the rooms were being cleaned, so there were both freshly cleaned and uncleaned rooms available. Facilities at the motor hotel also include a restaurant, kitchen, and cocktail lounge.

The most important observation made during the field tests was that, although the detector will stabilize in time in almost any atmosphere (the culture reaches a constant level of luminescence), its sensitivity varies from excellent to nonexistent depending on the background level in any specific location. If the atmosphere contains a high concentration of materials that elicit a positive response, the bacteria cannot respond sensitively to additional positive stimuli. Locker rooms, kitchens, and a cafeteria all caused the bacteria to maintain such a high level of luminescence that they could show no further response. It would be impossible to calibrate the detector response unless all characteristics of the ambient atmosphere could be controlled absolutely.

The time required to stabilize the detector varied with conditions. A change of a few degrees in temperature with the accompanying change in relative humidity usually required only a few minutes for detector stabilization. Atmospheric changes that included changes in the concentration of response-producing compounds required as long as 30 min for detector stabilization.

The detector sampling probe must be kept absolutely clean. Almost any contaminant in a probe will make it difficult or impossible for the detector to stabilize and will change the activity level at which stabilization is achieved, causing a change in detector sensitivity.

Not every detail of the field tests is reported; specific examples of the types of responses to be expected have been chosen for illustration.

1. High School Tests. The detector signal required 5 min to become stable after the detector was carried 100 yards from a heated car into the principal's office. It then required an additional 5 min to accommodate to the cooler hall outside the office. Each time the detector was taken into a cooler atmosphere it responded negatively, and each time the atmosphere was warmer it responded positively.

It gave positive responses to dirty urinals, a strong positive response to the (smoke-filled) teachers' lounge, and a very strong positive response to the rest room of the teachers' lounge, where there was a distinct odor of disinfectant. It gave a positive response to a locker that contained a student's lunch (a sandwich with mayonnaise), and a strong positive response to a locker containing a dirty tennis shoe. It gave a positive response to a room where a party (lemonade and cookies) was in progress, and a strong positive response to a taco being used for a food-preparation demonstration. It responded positively to a female teacher wearing perfume, to a dirty glove, to a sweater that had been worn recently, and gave strong positive responses to armpits.

The detector required 15 to 30 min to accommodate to the school cafeteria, and it could not detect anything after the signal became stable; the atmosphere in the cafeteria completely "blanked out" any further response. The gymnasium locker room produced the same type of response as the cafeteria, and sensitivity was greatly reduced in the main area of the gymnasium. Three different cultures were required for the 2-h test at the high school. Either stabilization in a high positive background or subjection to poisons shortens the cultures' lifetime; therefore, the detector must be checked often for response.

2. Motor Hotel Tests. The detector gave a strong positive response on entering the lounge area, and it showed distinctly reduced sensitivity after stabilization. It responded positively to olives and a condiment shelf in the lounge, but it did not respond to the beer tap. The detector required several minutes to stabilize after leaving the lounge, then it gave a very strong positive response on entering the kitchen. Sensitivity was almost completely nonexistent after stabilization in the kitchen, but there was a positive response to mustard and onions. A new culture was required after leaving the kitchen, and it required approximately 15 min to stabilize. Within the hallway of the rental units, the detector responded positively to dirty laundry, a candy machine, and a can of disinfectant aerosol. Doors to the rooms are sealed by a 1/4-in. foam gasket, but a positive response could be obtained at nearly every door tested. Some of the rooms had been freshly cleaned, and an odor of disinfectant was easily detected; other rooms had not been cleaned, and odors of smoke, perfumes, liquor, soap, etc., could be detected. All of the rooms gave a positive response on entering. An equipment-storage room that contained baby furniture also gave a positive response at the door.

3. Private Residence Tests. A strong positive response was obtained on entering, and there were specific positive responses to toilet bowls, peanut butter, and a lemon pie.

V. DETAILED CONCLUSIONS

(1) There is no single volatile compound or group of compounds given off by heroin at normal temperatures that is unique to heroin

(2) Heroin, itself, is not detectably volatile at normal temperatures; i.e., it is not detected by an analytical mass spectrometer at a pressure of 10^{-6} torr.

(3) All of the volatiles produced by heroin can be contained within common packaging materials, such as plastic films or foil.

(4) The response of RPC bioluminescent detectors near a heroin sample in equilibrium with a normal atmosphere is primarily caused by acetic acid, produced by hydrolysis of the heroin. It is not the result of interaction between heroin molecules and the bacterial cultures.

(5) Although the detectors are extremely sensitive to acetic acid, showing a response to approximately 50 ppb of acetic acid in air, they are also extremely sensitive to other low-molecular-weight organic acids.

(6) Acetic acid and compounds that produce a nearly identical response are extremely common; detectable amounts can be expected wherever there is a high level of human activity. False indications of heroin should be anticipated in any area of human occupation.

(7) The time required to stabilize the detector, following changes in temperature, humidity, and/or atmospheric contamination, must be considered in planning practical operations.

(8) The detector sensitivity is a function of the background concentration of compounds that cause a response from the bacterial cultures. When the composition of the atmosphere surrounding the detector changes, the sensitivity of the detector changes.

VI. DETAILED RECOMMENDATIONS

Two specific recommendations were requested in the interagency agreement that defined this project.

(1) A recommendation on the usefulness of the detector "--- for detection of heroin, from outside a room in which it is being handled" was requested. Volatiles are the only compounds that could be expected to be detectable outside a closed door with any reliability, and acetic acid is the only volatile given off by heroin that causes a major detector response. Doors can be temporarily sealed by simple measures, the atmosphere of a large building can easily be contaminated with enough acetic acid to overwhelm a detector, and acetic acid is normally present in detectable concentrations in occupied buildings. Field tests showed that the contaminated atmosphere of a building reduced the detector's sensitivity to any specific source of acetic acid, and appreciable time for detector stabilization was often required during a test involving a series of doors. Therefore, an acetic acid-sensitive detector cannot be recommended as a practical tool for detection of specific locations where heroin is being handled by making a door-to-door search of occupied buildings.

(2) A recommendation "--- as to the potential of bioluminescent detectors for heroin" was also requested. We believe that two aspects of the problem should be addressed separately, as follows.

(a) The sensitive acetic acid detectors considered can be useful in specific conditions. For example, when it is known that heroin is hidden within part of a large container or structure that is unlikely to contain another source of acetic acid (in a safe, in the door panel of an automobile, between the panels of a wall, etc.), the presence and/or specific location of an unsealed heroin sample could probably be determined. Existing detectors can be recommended for such applications, because their sensitivity and specificity are adequate.

(b) There is no evidence that the heroin molecule affects the metabolism of bioluminescent bacteria. Therefore, it is extremely doubtful that any amount of research would lead to a bioluminescent system that would be both specific for heroin and sensitive enough to detect the minute concentrations of heroin vapor given off by a heroin sample at ambient temperatures. Of the more volatile compounds normally associated with heroin, no single compound or combination of compounds is specific to heroin, and their relative concentrations vary with the history of the sample and with ambient conditions. It would be extremely difficult and expensive to develop any type of instrument with assured specificity to heroin that was based on the analysis of volatile components associated with heroin. Therefore, we do not recommend further research directed toward the development of heroin-specific bioluminescent detectors.

(3) We can make one minor recommendation, resulting from the detector studies. Additional testing could help to determine the quantitative advantage to be gained by use of an acetic acid detector for searches of the type indicated in (2a). Such tests should be conducted by police personnel working under actual field conditions. The sensitivity of the RPC Model 2032-14 unit with a positive bacterial culture is at least as good as that of the other two models tested, its response rate is good, it is easily portable, and its specificity is adequate for any situation that permits use of an acetic acid detector. Therefore, we recommend that further field testing, if any, by police personnel be done with the model 2032-14 detector.

Note that many of the limitations of bioluminescent systems discussed here are specific to their application in heroin detection. Every proposed application of a bioluminescent system should be judged on its own merits.

END