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Protection Afforded by Experimental XXCC3-Impregnated Navy Work/Combat Clothing Worn by Men Exposed to Mustard Vapor

by

Fred W. Oberst
Nelson P. Musseman
Clyde H. Graf
George A. Trapp
Paul B. Dawson

February 1965

EDGEWOOD ARSENAL, MARYLAND 21010
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PROTECTION AFFORDED BY EXPERIMENTAL IMPREGNATED NAVY WORK/COMBAT CLOTHING WORN BY MEN EXPOSED TO MUSTARD VAPOR

by

Fred W. Oberst
Nelson P. Musselman
Clyde H. Graf
George W. Trapp
Paul B. Dawson

Toxicology Division
Directorate of Medical Research

February 1965

US ARMY EDGEWOOD ARSENAL
CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES
EDGEWOOD ARSENAL, MARYLAND 21010
FOREWORD

This work was authorized under Project IC622401A097, Medical Defense Aspects of Chemical Agents (II), Task IC622401A0970, investigation and Evaluation of Protective Equipment, conducted under Directorate of Medical Research approved Research Plan 5043. Work was funded in part by the US Naval Supply Research and Development Facility, Navy Supply Center, Bayonne, N. J., Bureau of Supplies and Accounts, Department of the Navy, subtask 80-02-001-002-1-1-1-3, MIPR 920-7215164, 2 March 1964. The work was started in June 1964 and completed in August 1964. The experimental data are contained in notebook IC622-401 A097.

ACKNOWLEDGMENTS

The authors acknowledge the cooperation of Lt Col Nicholas Bottiger and Mr. Carl Siebert from Clinical Research Division in providing the volunteers, the volunteers for their service, Mr. Marshall F. Gilchrist, Mr. John Deppisch, S/Sgt Arne Rosenberg, Sp5c Walter Hunt, Mr. Thomas Mitchell, and Pfc William Konzal, from Physical Protection Division, for suggestions offered and for the proper fitting of protective masks and clothing on the subjects. The technical assistance of Pfc Donald Swan from Vapor Toxicity Branch in the analysis of mustard vapor is acknowledged. The authors are also grateful to Mr. Elmo Maiolatesi for fabrication of the mustard-crossover bubbler, to Dr. Harold Averill, Coordinator of Research and Protection, Directorate of Medical Research, and to Mr. Maurice Weeks, Vapor Toxicity Branch, and Mr. Edward Cheroverier, of the US Naval Supply Research and Development Facility, for helpful suggestions.

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DIGEST

The effectiveness of Navy protective clothing (single-layer type) impregnated with XXCC3 against mustard vapor (20 mg/cu m) was tested by 10 men. Two men serving as control the standard Army two-layer XXCC3-treated protective clothing and were exposed with the group. When mustard vapor penetrated the Navy clothing, erythema developed at the site of penetration within 24 hr after exposure. When this occurred, the affected subject was withdrawn from further exposure tests. The men were exposed for 15 min on the first day, 30 min on the second day, and 1 hr on each of the following 8 days. Erythema was produced on 9 of the 10 men wearing Navy clothing exposed in the cumulative Ct range of 3,306 to 10,054 mg min/cu m, with corresponding cumulative exposure times varying between 2.75 and 8.35 hr. Most of the erythema occurred in the abdominal area. The one remaining Navy suit and the two control Army suits did not break during the 10 exposures, which totaled cumulative Ct's of 10,500 mg min/cu m and 8.75 hr.

Considerable care in size selection and adjustment of the Navy clothing outfit on the wearers was necessary to assure the absence of gaps in protection over the forearms and around the waist.

It is concluded that the experimental XXCC3-impregnated Navy work/combat clothing can be worn by men in mustard vapor for a cumulative Ct of 7,000 mg min/cu m (total time 6 hr) without incapacitating effects.
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PROTECTION AFFORDED BY EXPERIMENTAL XXCC3-IMPREGNATED NAVY WORK/COMBAT CLOTHING WORN BY MEN EXPOSED TO MUSTARD VAPOR

I. INTRODUCTION.

The US Army Edgewood Arsenal Chemical Research and Development Laboratories were requested to furnish the necessary services, personnel, facilities, and supplies required for the evaluation of experimental XXCC3-impregnated Navy work/combat clothing. The purpose of this evaluation was to determine whether these garments fulfill the requirements as protective suits against chemical agents. The garments were evaluated by exposing volunteers to mustard vapor in a chamber.

II. EXPERIMENTATION.

A. Materials and Equipment.

Chloropicrin was utilized in the leak testing of the protective masks worn by the volunteers. The mustard was plant-distilled and its purity reported to be from 95% to 98%.

The clothing was supplied by the US Naval Supply Research and Development Facility, Navy Supply Center, Bayonne, N. J. The complete protective outfit consisted of a shirt, trousers, hood, socks, cotton gloves, plastic booties, and plastic gloves. All of the items of clothing except the plastic gloves and booties were impregnated with XXCC3. The shirts were fabricated from 6.2-oz nylon-cotton poplin and were of a pullover type. They were worn on the outside of the trousers and were drawn tight at the bottom with a drawcord. The trousers and hood were made from 8.8-oz nylon-cotton sateen. The socks and cotton gloves were standard items and were worn over the trouser legs and shirt sleeves. The hood had a front and back bib and an inner circular protective flap attached to the neckline. It had two drawstring adjustments, one at the forehead and another on the inner cheek flap, to prevent vapor entrance. The bib was designed to cover the front opening of the shirt. To complete the Navy outfit, each man wore the Mk V gas mask.

These Laboratories supplied unimpregnated shorts, T-shirts, and untreated leather Army combat boots. The two control subjects wore the standard US Army two-layer XXCC3-impregnated clothing for comparison. Figures 1 to 8 illustrate the Navy and Army clothing used in these tests in different stages of dressing.
FIGURE 1

SUBJECTS WEARING NAVY UNIMPREGNATED T-SHIRT AND SHORTS (LEFT) AND ARMY IMPREGNATED LONG UNDERWEAR (RIGHT)

FIGURE 2

NAVY TROUSERS, SOCKS, AND SHOES DONNED
AROUND NECK PRIOR TO FITTING
NAVY GLOVES DONNED, HOOD SLUNG

FIGURE 4

NAVY JACKET WORN OVER T-SHIRT

FIGURE 5
**FIGURE 5**

NAVY GAS MASK DONNED, FRONT AND BACK BIB OF HOOD IN PLACE

**FIGURE 6**

FRONT VIEW OF COMPLETELY DRESSED SUBJECTS

Left - Arr. clothing
Right - Navy clothing including plastic booties over boots
FIGURE 7
BAR VIEW OF COMPLETELY DRESSED SUBJECTS
Left - Army clothing
Right - Navy clothing

FIGURE 8
SUBJECTS LEAVING GASSING CHAMBER
(Last individual is wearing Army clothing as control)
B. Procedures for Chamber Operation and Analysis of Mustard-Vapor Concentration.

A 20-cu m dynamic gassing chamber was used in the mustard tests. The airflow was 5,000 l/min. Dry nitrogen was passed through the liquid mustard at 114°C in a specially designed bubbler (figure 9) at a rate of approximately 2 l/min to give a chamber concentration of 20 mg/cu m.

The mustard concentration in the chamber was determined on samples of chamber air by a bromine titration method using the modified Northrup manual electrolytic titrimeter. A sample was collected and analyzed every 3 min. The cumulative C's were determined during the progress of an exposure.

Subjects.

1. Selection and Use.

The volunteers selected for this study were made available by the Clinical Research Division. They were divided into two groups (A and B) of six men each, five wearing the Navy clothing and one wearing the Army control clothing. For the first eight exposures, group A was exposed in the morning and group B in the afternoon. In the ninth and tenth exposures the men from both groups who had not developed erythema (totaling five men in this instance) were exposed as one group. No exposures were made on Saturdays or Sundays. Each subject had previously been examined by a physician (figure 10) for skin rash and other dermatological conditions that might mask the mustard effect if a clothing break and erythema were to occur.

2. Dressing and Preparation of Subjects for Mustard Test.

The subjects were dressed by clothing specialists to assure proper wearing of the clothing and proper fitting of the protective mask and hood. Amyl acetate vapor from a bottle of the liquid was applied to the periphery of the mask to check for gross leaks. A further mask-leakage test was made by exposing the men to chloropicrin in a gassing chamber. In the chamber a series of physical exercises was performed for 5 min to ascertain that the mask was properly fitted and would not leak while being worn in mustard vapor.
FIGURE 9

BUBBLER FOR DISPERSING MUSTARD VAPOUR
FIGURE 10

EXAMINATION OF SKIN BY PHYSICIAN PRIOR TO EXPOSURE
3. Exposure of Subjects to Mustard.

The procedure for exposure to mustard vapor is similar to that previously described.\(^3,4\) After the chlorine rinse test, the men entered the mustard chamber and remained for a period of 15 to 60 min. The men were exposed daily to mustard vapor at increasing Ct's (C = 20 mg/cu m, t = 15 to 60 min), but not exceeding 1,218 mg min/cu m any one day. No man received more than 10 exposures or a maximum cumulative Ct of 10,500 mg min/cu m. The men were instructed to leave the chamber if they detected, or thought they detected, an odor of mustard. During the exposure, each man was in full view of the observers and in contact with them by an intercommunication system. The temperature of the exposure chamber was 240 to 270°C (average 250°C), and the relative humidity was 58% to 70% (average 65%). The men were allowed freedom of movement during exposure, but they were requested not to sit down or lean against the chamber walls. During the final 15 min of the last eight exposures, the men were directed to walk in a circle and to step on and off an 8-in. high concrete block approximately twice per minute to flex the clothing further.

To assure the safety of the subjects, a physician was in attendance. After the mustard exposure, the men remained in the anteroom 4 min to aerate their clothing. They were then escorted outside for an additional 20 min aeration. They were assisted by clothing experts in removing their contaminated clothing. The clothing was hung in a well-ventilated room until the next exposure day. After a shower, observation, and a discussion of the day's proceedings, the men were dismissed.

Twenty-four hours after each exposure, a physician carefully examined the subject for mustard effects. If erythema was seen, the subject was withdrawn from further exposures, and the cumulative Ct was considered the breaking point for that particular garment.

D. Mustard-Vapor-Penetration Tests.

Samples of cloth were cut from the Navy protective clothing before and after the clothing was exposed to mustard vapor in the wearing trials. These samples were tested for concentration of chloramide as free chlorine\(^5\) and for mustard penetration (µg/sq cm) under standard conditions by the Dawson Agent Test apparatus.\(^*\) The results were compared with those for the Army 8.5-oz, one-layer, XXCC3-impregnated sateen fabric.

The general procedure for the mustard-penetration test is as follows: Mustard vapor (20 to 25 mg/cu m at 80% relative humidity, dry-bulb temperature 90°F) is drawn through test fabric at a velocity of 10 cm/min for 6 hr, with intermittent penetration samples being collected in bubblers at 0 to 2 hr and 2 to 6 hr. The effluent mustard concentration is analyzed by the DB3 method* and expressed as micrograms per square centimeter for the collection time indicated.

III. RESULTS.

Table 1 shows the daily exposure time and the cumulative Ct for each of the two groups of subjects. The longest cumulative exposure time was 8.75 hr, with an average cumulative Ct exposure of 10,500 mg min/cu m. Table 2 gives the number of exposures to mustard vapor and the cumulative Ct exposure values for clothing breaks after which erythema was observed.

No erythema was seen in either of the two subjects wearing the standard Army impregnated ensemble or in one subject wearing the impregnated Navy clothing for 10 days, the duration of the test. Nine Navy suits broke between cumulative Ct's of 3,300 and 10,000 mg min/cu m. The first one broke after the fourth exposure. Another broke on the fifth day, three on the seventh day, two on the eighth day, and two on the tenth day.

The erythema usually was present on the abdominal or chest area close to the waistline. In one man it was present on the scrotum, and in two men it was present about the groin and trigonal area.

Table 3 shows average values for samples from Navy unexposed and exposed clothing items evaluated in the laboratory for chloramide content and mustard-vapor penetration. The mustard tests did not appreciably deplete the chloramide content of the fabric, and the penetration of mustard through the fabric was not appreciably altered by the wearing trials. Laboratory tests showed that the nylon-cotton Navy and Army sateen fabrics are comparable in chloramide content and in protection provided.

### TABLE 1

**DAILY EXPOSURE TIMES AND CUMULATIVE Ct's RECEIVED BY SUBJECTS WEARING TEST CLOTHING IN MUSTARD VAPOR**

<table>
<thead>
<tr>
<th>Exposure day</th>
<th>Group A (morning)</th>
<th>Group B (afternoon)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure time</td>
<td>Ct</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>mg min/cu m</td>
</tr>
<tr>
<td>1st</td>
<td>15</td>
<td>294</td>
</tr>
<tr>
<td>2nd</td>
<td>30</td>
<td>606</td>
</tr>
<tr>
<td>3rd</td>
<td>60</td>
<td>1,206</td>
</tr>
<tr>
<td>4th</td>
<td>60</td>
<td>1,200</td>
</tr>
<tr>
<td>5th</td>
<td>60</td>
<td>1,218</td>
</tr>
<tr>
<td>6th</td>
<td>60</td>
<td>1,200</td>
</tr>
<tr>
<td>7th</td>
<td>60</td>
<td>1,200</td>
</tr>
<tr>
<td>8th</td>
<td>60</td>
<td>1,188</td>
</tr>
<tr>
<td>9th</td>
<td>60</td>
<td>1,194</td>
</tr>
<tr>
<td>10th</td>
<td>60</td>
<td>1,194</td>
</tr>
<tr>
<td>Total</td>
<td>8.75 hr</td>
<td></td>
</tr>
</tbody>
</table>

Exposure time
<table>
<thead>
<tr>
<th>Subject number</th>
<th>Number of exposures</th>
<th>Cumulative exposure time</th>
<th>Cumulative Ct (mg min/cm²)</th>
<th>Report of physician's examination 24 hr after last exposure</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>6A</td>
<td>10</td>
<td>8.75</td>
<td>10,506 No erythema</td>
</tr>
<tr>
<td></td>
<td>6B</td>
<td>10</td>
<td>8.75</td>
<td>10,494 No erythema</td>
</tr>
<tr>
<td>A. Army Clothing (Controls)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4A</td>
<td>4</td>
<td>2.75</td>
<td>3,306</td>
<td>Erythema (4'- X 8-in.) on mid abdomen above umbilicus</td>
</tr>
<tr>
<td>4B</td>
<td>5</td>
<td>4.5</td>
<td>5,424</td>
<td>Mild erythema (3'- X 3-in.) on upper chest about breast</td>
</tr>
<tr>
<td>1B</td>
<td>7</td>
<td>5.75</td>
<td>6,918</td>
<td>Moderate erythema at beltline</td>
</tr>
<tr>
<td>2B</td>
<td>7</td>
<td>5.75</td>
<td>6,918</td>
<td>Moderate erythema (6'- X 8-in.) on anterior abdomen</td>
</tr>
<tr>
<td>6B</td>
<td>7</td>
<td>5.75</td>
<td>6,918</td>
<td>Moderate erythema in trigonal area and about beltline</td>
</tr>
<tr>
<td>1A</td>
<td>8</td>
<td>6.75</td>
<td>3,124</td>
<td>Erythema about groin</td>
</tr>
<tr>
<td>5A</td>
<td>8</td>
<td>6.75</td>
<td>3,124</td>
<td>Erythema on abdomen</td>
</tr>
<tr>
<td>2A</td>
<td>10</td>
<td>8.35</td>
<td>10,054</td>
<td>Erythema (8'- X 12-in.) with one vesicle on abdomen, erythema under chin (approximately 1'- X 2-in.)</td>
</tr>
<tr>
<td>3A</td>
<td>10</td>
<td>8.35</td>
<td>10,054</td>
<td>Moderate erythema on scrotum, with burning sensations</td>
</tr>
<tr>
<td>5B</td>
<td>10</td>
<td>8.75</td>
<td>10,494</td>
<td>No erythema</td>
</tr>
<tr>
<td>B. Navy Clothing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 3

LABORATORY EVALUATION OF NAVY PROTECTIVE CLOTHING BEFORE AND AFTER CLOTHING WAS EXPOSED TO MUSTARD VAPOR IN WEARING TRIALS

<table>
<thead>
<tr>
<th>Clothing items sampled</th>
<th>Chloramide content as free chlorine (average)</th>
<th>Mustard-vapor penetration of fabric (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of samples</td>
<td>Unexposed clothing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hood</td>
<td>2</td>
<td>0.765</td>
</tr>
<tr>
<td>Jacket</td>
<td>2</td>
<td>0.460</td>
</tr>
<tr>
<td>Trousers</td>
<td>2</td>
<td>0.564</td>
</tr>
<tr>
<td>Army A, 5-oz treated sateen</td>
<td>1</td>
<td>0.600</td>
</tr>
</tbody>
</table>

* For each condition; i.e., unexposed and exposed clothing.
IV. DISCUSSION.

The type of protective clothing used in the Navy study was the so-called one-layer system. Only the outer layer was impregnated; the underwear was the standard unimpregnated T-shirt and shorts. In contrast, the Army clothing used as a control consisted of two layers of clothing; both the outer garment and the long-sleeved undershirt and long-legged underpants were impregnated. It would be unreasonable to expect a one-layer system to afford more protection than a two-layer system. Mustard vapor penetrates by slipping through the treated fabrics and through inadequacies of closures; i.e., cuffs, collar, etc.

Although the Navy one-layer suit was inferior to the Army two-layer suit in protection against mustard vapor, it was considered to be safe for a wearing period of at least 1-3/4 hr without resulting in burns. This represents a mustard vapor cumulative Ct of 2,100 mg min/cu m for three wearing trials. The erythema noted in the first individual occurred from a cumulative exposure above this Ct and below 3,306 mg min/cu m. The second person to receive a burn acquired it between cumulative exposures of 3,300 and 5,400 mg min/cu m. The burns in these two subjects were quite mild and were not incapacitating. Those burns merely indicate that an endpoint had been approached. In fact, one-half of the men (five) did not develop erythema until a Ct of 7,000 mg min/cu m or higher was reached. Figure 11 shows three subjects with burns on the abdomen.

Laboratory tests for chloramide content and mustard penetration of fabric suggest that the protection afforded by the suits did not deteriorate after mustard exposures, but that the resulting erythema was primarily a cumulative effect of the slight slipping that occurred over a period of time. No doubt, if another individual wore the same suit and were exposed, he would not develop erythema before the Ct that caused erythema in the previous wearer was reached.
FIGURE 11

ENDPOINT OF CLOTHING PROTECTION RESULTING IN ER'S THEMED IN SUBJECTS EXPOSED TO MUSTARD VAPOR

(Top, subject 4A; bottom left, 2A; bottom right, 1A)
Several comments may be made as to the fitting of the clothing, although this probably had no bearing on the mustard burns. Attempt was made to fit the proper-sized uniform to the man according to his height and weight, as indicated on Army TECOM 8-4-6230 ("Sizing and Fitting Worksheet"). Some suits, which should have been satisfactory according to the labeled size and the worksheet, were much too small, and it was necessary to substitute a larger suit. In particular, the sleeves were very short and the cuff closing gapped (figure 3), making it difficult to seal. The long white protective gloves were intended to cover the gap in the sleeves. When this was impossible, a shirt with longer sleeves was substituted. In all cases it was necessary to pin the glove cuff to the sleeve above the gap. The neck portion of the hood also was very tight and tended to pull the mask off the face when the subject pushed his head forward. The inner circular protective flap on the underside of the hood was considered unnecessary in a test of this nature. The flap was not placed under the shirt as designed (figures 5 and 6).

V. CONCLUSION.

It is concluded that the experimental XXCC3-impregnated Navy work/combat clothing can be worn by men in mustard vapor for a cumulative Ct of 7,000 mg min/cu m (total time 6 hr) without incapacitating effects.
LITERATURE CITED


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<td>ORIGINATING ACTIVITY (Corporate author)</td>
<td>US Army Edgewood Arsenal Chemical Research and Development Laboratories, Edgewood Arsenal, Maryland 21010 Toxicology, Clinical Research, and Physical Protection Division</td>
</tr>
<tr>
<td>REPORT SECURITY CLASSIFICATION</td>
<td>UNCLASSIFIED</td>
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<td>GROUP</td>
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**REPORT TITLE**

PROTECTION AFFORDED BY EXPERIMENTAL XXCC3-IMPREGNATED NAVY WORK-COMBAT CLOTHING WORN BY "EN EXPOSED TO MUSTARD VAPOR

**DESCRIPTION NOTES**

The work was started in June and completed in August 1964

**AUTHORS**

Oberat, Fred W Trapp, George A Musselman, Nelson P Dawson, Paul B Graf, Glyder J

**REPORT DATE**

February 1965

**TOTAL NO OF PAGES**

25

**TOTAL NO OF REPS**

5

**PROJECT NO**

IC622401A097

**DLIR**

3254

**OTHER REPORT NO(S) (Any other numbers below) - assigned this report**

N/A

**AVAILABILITY/LIMITATION NOTICES**

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**SUPPORTING MILITARY ACTIVITY**

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**ABSTRACT**

The protective effectiveness of Navy protective clothing (single-layer type) impregnated with XXCC3 was tested by exposure. Ten men wearing the outfit in an atmosphere of mustard vapor (10 mg/cu m) and ten men serving as controls wore the standard Army two-layer XXCC3-treated protective clothing and were exposed with the group. The men were exposed for 15 min on the first day, 10 min on the second day, after which the daily exposure was 1 hr on the following 8 days. When mustard vapor penetrated the Navy clothing, erythema developed at the site of penetration within 24 hr after exposure. When this occurred, the affected subject was withdrawn from further exposure tests. Erythema was produced on nine of the ten men wearing Navy clothing exposed in the test atmosphere of 10 mg/cu m, with corresponding cumulative exposure times varying between 21 and 3.5 hr. Most of the erythema occurred in the abdominal area. The remaining one Navy suit and the two control Army suits did not break during the 10 exposures totaling cumulative Cts of 10,500 mg min/cu m and 875 hr. The Navy clothing outfit required considerable care in fire selection and adjustment on the wearers to assure the absence of gaps in protection in front of and around the waist. It is concluded that the experimental XXCC3-impregnated Navy work/combat clothing can be worn by men in mustard vapor for a cumulative Ct of 7,000 mg min/m (total time 6 hr) without incapacitating effects

**KEYWORDS**

- XXCC3
- Exposures
- Arming trials
- Mustard vapor
- Navy clothing
- Incapacitation
- Penetration
- Concentration
- Cumulative Ct
- Combat-work clothing
- Years
- Protective clothing
- Incapacitation
- Clothing trials
- Impregnated clothing
- Gt cap
- Impregnated
- Yd cap
- Must-chem
- Chem-ear
- Sing-layer ch.
- Irr an investigation
- Two-layer clothing
- Army clothing

**DD Form 1473**

25 UNCLASSIFIED

Security Classification
PROTECTION AFFORDED BY EXPERIMENTAL XCC3-DEPLOYED NAVY WAVE CLOTHING WORKED OUT BY AND ENSIZED TO HOSTA, J. VAPOR
US ARMY EDGWOOD ARSENAL
CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES
Technical Report CHEC 3258
February 1955
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