Fig. 2.22

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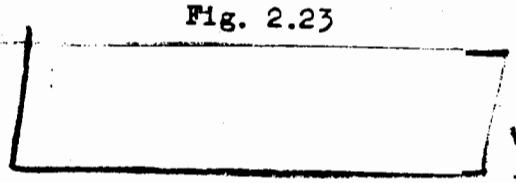
Fig. 2.23



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2.6 THE BOOSTER

The operation of the Booster is described in some detail in Chap.3 of this volume so we shall give here only a brief description.

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Fig. 2.24

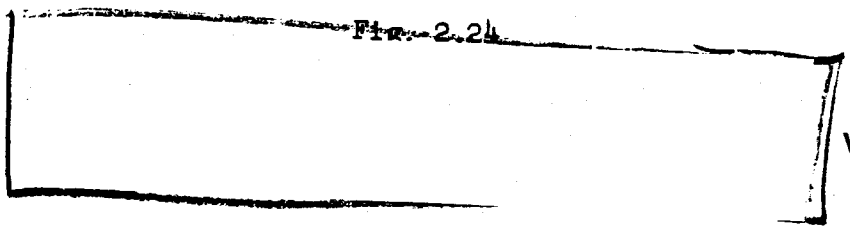

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Fig. 2.25

Reaction Rate as a Function of Time

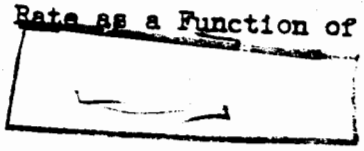

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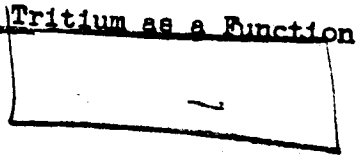
Fig. 2.26

Depletion of Tritium as a Function of Time



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When the D-T reaction goes, a flood of 14-Mev neutrons is released which then cause fissions in the surrounding material. The fission rate is thus "boosted" so that the resulting yield is much larger than would have been the case had no D-T reaction occurred. This sudden boosting of the fission reaction will, of course, accelerate the disassembly of the active material. For this reason, the amount by which the yield will be boosted will depend upon when the D-T reaction occurs.

CHAPTER 3

DIAGNOSTIC MEASUREMENTS

B. R. Suydam

3.1 INTRODUCTION

It is the purpose of the Greenhouse experiments to test weapons of two categories, normal fission bombs and experimental bombs containing a mixture of deuterium and tritium.

Because of the existence o this second category of weapons, the diagnostic experiments will be far more complex than those which have been done in the past.

This chapter naturally divides into two main sections. In the first of these we shall discuss the diagnostic experiments to be performed on the normal fission weapons. The second section will be devote to a description of the experiments which are designed to study the thermonuclear D-T reaction.

3.2 DIAGNOSIS OF THE FISSION REACTION

The main features of a nuclear explosion and the theory of the three crucial diagnostic measurements thereof have been adequately described elswhere[1] and will be assumed known to the reader. Suffice it

[1] Scientific Director's Report for Operation Sandstone, Vol III (Sandstone No. 9).

I vs t curve. This means that currents must be measured to high precisio in order that the gamma flux versus time may be deduced with only modest accuracy. For a scintillation detector, on the other hand, the light out put of the phosphor, and hence the plate current of the photoelectric cel used to measure this light, is proportional to the instantaneous value of the gamma flux. The resulting gamma flux vs time curve is therefore just as accurate as the recorded current vs time curve. Of course any electrical distortion present in the recording circuits will modify the above statements for both ionization-chamber and scintillation detectors, but i will do so in a known and calculable fashion.

The alpha-measuring experiment will involve a number of gamma-ray detectors adjusted by means of distance and gamma-ray absorbers to respond to various portions of the wide range of prompt gamma-ray intensities encountered during the nuclear reaction. Common timing will be provided so that the relative times at which the various detectors respond will be determined. This common timing scheme will thus enable one to fit the various records together in time and so produce a complet curve of prompt gamma-ray intensity vs time, extending from the lowest detectable level to the highest which occurs. It is expected in this way to follow the nuclear reaction from a very low level (a few pounds o TNT equivalent) through its maximum and well out into the region where alpha becomes negative. As mentioned previously the principal detectio scheme will employ scintillators. A back-up scheme using Rossi-type

chambers will also be employed, principally because this has been our past method for measuring alpha.

It will be seen from the foregoing description that the alpha experiment is much more elaborate than is strictly required to diagnose the performance of a fission bomb. Accordingly, the results of the experiment will give much more information than merely the answer to the question: was the explosion typical?

hydrodynamics of the early stages of this process is quite simple and amenable to calculation. Alpha measurements which extend from very low reaction levels into the region where alpha begins to drop are therefore very valuable for two reasons. The mathematical form of the alpha versus time curve in this region can be calculated theoretically; a measurement in this region therefore affords a check on theory. Moreover, theory provides us with a correlation between the absolute fission level of the bomb and the break in alpha. This enables us to assign an absolute level to any portion of the fission reaction[4] and to determine the important quantity τ_o, the number of gamma photons escaping the assembly per fission.

Recent improvements in the theory on one hand and the use of differential detectors on the other will give much more accurate results for the Greenhouse shots. The real importance of the quantities τ_o and the absolute level will be apparent later when we discuss thermonuclear reactions.

[4] This statement is not strictly true for very late stages of the fission reaction, when alpha is very small and the prompt gamma rays are not simply correlated to the fission rate.

dosage received as a function of distance should give an accurate rela
tive yield determination. In contrast with the ball-of-fire method,
this scheme has not been accurately calibrated. It is expected, howev
that sufficiently accurate gamma-ray detectors will be used in the
Greenhouse tests and that a good calibration of this method will resul
This, if achieved, will be an important result, as conditions are con-
ceivable (such as an underground or underwater shot) which would make
other methods of yield determination difficult, if not impossible.

A fifth method of determining yields, which depends on
blast scaling laws, is to measure the time between the first appearanc
of light and the minimum of the light curve. This is accomplished by
an instrument which was named the bhangmeter by F. Reines, who propose
this method. The bhangmeter will be used for the Greenhouse shots, bu
more as a test of the instrument than as a device for measuring yields

3.3 DIAGNOSTIC EXPERIMENTS FOR WEAPONS WHICH INVOLVE A THERMONUCLEAR REACTION

A thermonuclear reaction is, as its name implies, a reaction br
about by collisions between nuclei which are induced by their thermal
agitation. As the coulomb barrier of any nucleus is high, only nucle
of the smallest possible charge can be considered if one is not to re
prohibitively high temperatures. In addition, if the reaction is to
place fast enough that an appreciable amount of material reacts, muc
are required which have a large cross section for the reaction in que

bremsstrahlung, that is, the radiation of electromagnetic energy and loss of kinetic energy of an electron which is deflected by the coulom field of a nucleus. The third cooling agent is the inverse Compton effect. When electrons and photons collide, energy is transferred fro one particle to the other. If the electrons are more energetic on the average than are the photons, the electrons will lose energy on the average and the radiation field will gain. Inverse Compton effect ten therefore to equalize the "temperatures" of the radiation field and th electron gas.

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3.3.1 The Booster

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Merely a yes or no answer to the question whether some tritium has burned can hardly be called a detailed study of the thermonuclear reaction. In addition to this information it would be desirable to know the answers to the following questions:

1. How much tritium has reacted?
2. At what nuclear temperature did the reaction go?
3. At what density did the reaction take place?
4. What was the reaction rate?
5. What was the state of the material in the vicinity of the D-T mixture when the reaction started?

It is the purpose of the diagnostic experiments to answer some of these questions.

3.3.3 Determination of the Amount of Tritium Consumed

The experiments designed to determine how much tritium burned depend on the fact that every tritium atom consumed releases a 14-Mev neutron, whereas, the fission reaction yields very few neutrons as energetic as this. Thus any experiment which measures the high-energy neutron yield is a potential handle on this important question.

One method of obtaining the high-energy neutron yield is the use of threshold neutron detectors placed at various distances from the bomb. By obtaining in this fashion a high-energy neutron flux versus distance curve, the source strength of the bomb can be obtained.

true if the particles react in flight. In the latter case, the neutron emitted, when observed in the center-of-gravity system of coordinates, would have an energy of 14 Mev plus four-fifths of the kinetic energy carried into the reaction by the reacting particles. Actually, of course, the center of mass of the reacting particles will be in motion relative to the observer, so that there will be a Doppler energy shift superimposed on the energy in the center-of-mass system. Thus, the neutrons released by the D-T reaction will have energies which cover a band in the neighborhood of 14 Mev, with the band being broader the higher the velocity of the reacting particles, i.e., the higher the nuclear temperature. It is relatively easy to show that the velocity distribution is roughly Gaussian with a half-breadth dependent on the temperature.

The Tenex experiment will determine the distribution of the 14-Mev neutrons in velocity, by placing scintillation detectors at a considerable distance from the explosion so that neutrons of various energies are separated by noting their arrival time. In order that spuriously long times of flight, caused by air scattering of the neutrons, may be eliminated, the detectors must be placed behind collimating tubes. These tubes will contain lead absorbers to reduce the gamma-ray background.

Two stations will be employed for this experiment, one at 200 and one at 1,000 yd. The time resolution, about 0.1 microsecond, will not be sufficient to give a velocity resolution at the near station. The purpose of this station is to enable one to subtract, from the data

yielded by the far station, any finite neutron pulse breadth which is caused by finite burning time rather than a velocity spread. The resulting neutron intensity versus time curve will give some sort of an average nuclear temperature for the reaction.

3.3.5 Determination of Density

An ingenious experiment has been devised for determining the density of the D-T mixture at the time the thermonuclear reaction takes place.

The success of this experiment evidently depends on a determination of the amount of tritium consumed.

3.3.6 Determination of the Reaction Rate: The Dinex and Ganex Experiments

It was pointed out by W. E. Ogle and F. Reines[7] that a time-dependent study of the 14-Mev neutrons from a reacting bomb assembly could give considerable information. In the first place, in principle, such measurements can yield information regarding the fission rate as a function of time in a much cleaner fashion than can the conventional alpha measurements (we are here concerned with the varying alpha region) because the processes involved are much simpler.

[7] See LAMS-1062, LAB-J-655 and LAB-J-711 for early considerations of this experiment.

[8] This statement is true only for fissions induced by thermal neutrons. The 14-Mev neutron yield can, however, be determined for other neutron energies.

In addition to the Dinex experiment discussed above, there is the Ganex experiment, which is also designed to measure the D-T reaction rate as a function of time. The Ganex experiment also utilizes the 14-Mev neutrons released by the D-T reaction, but the detection scheme is different.

In the Ganex experiment, the 14-Mev neutrons, after passing through a collimator (not, however, a particularly good one), are allowed to fall on an iron converter. The iron inelastically scatters the high-energy neutrons, thus giving rise to gamma radiation. A scintillation gamma-ray detector is then placed behind a collimator which points at the iron converter; the gamma rays from this converter are thus measured as a function of time.

As compared with the Dinex experiment, the Ganex experiment has one definite virtue and two definite disadvantages. In the Ganex experiment the iron converter will be placed in the tower cab and the gamma detectors will be placed on the ground near the base of the tower. Thus, the severe problem faced by the Dinex experiment, i.e., the transmission of signals down the tower over transmission lines which are subjected to a large gamma flux, is avoided in the Ganex experiment. The Ganex experiment suffers the disadvantage of the lack of a clean energy discrimination and therefore will not work at low levels, for the background from fission neutrons and gamma rays will obscure such signals. The complicated intermediate processes, i.e., the inelastic scattering of neutrons and (n,γ) reactions in iron, make it much more difficult to interpret current at the detector in terms of an absolute reaction rate

[redacted]

The mechanism of X-ray absorption is the photoelectric effect, i.e., the absorption of photon accompanied by the ejection of a bound electron. The energy of the photon which was destroyed is imparted to the electron which therefore escapes its atom with an energy equal to that of the absorbed photon minus the binding energy of the electron. Following the photoelectric ejection of an electron there will be an unoccupied "hole" in one of the electron shells (usually the K-shell) into which an electron will drop from some outer shell. This gives rise to the emission of an X-ray photon characteristic of the transition involved; the process is known as fluorescence. The frequency of the fluorescent radiation will evidently depend on the shell from which photoelectrons are ejected; thus if K-shell

electrons are ejected, the characteristic K-radiation will result.

The operation of the X-ray detectors can be understood in the light of the preceding discussion. Primary X-radiation from the bomb is allowed to fall on a metallic sample, which takes the form of an appropriate compound (a benzoate or a tartrate) dispersed in polystyrene. The resulting flourescent radiation is then passed through a berylium window which serves to stop photo-electrons and partially to filter out low energy flourescent radiation. The remaining flourescent radiation fall on a metallic plate from which it ejects photo-electrons which are collected by a ten kilovolt electric field. Because of the strong energy dependence of the photoelectric effect the luminescent efficiency and the filtering action combine to make a detector which is sharply energy selective. Four groups of detectors will be used, each group in a separate X-ray beam, and each peaked at a different energy. There are three groups of three detectors each and one group of two detectors making eleven in all.

As with the Dinex experiment, serious difficulties are introduced by the magnitudes of the primary signals involved. However, the struggle there was always to gain signal level, whereas, the X-ray experiment is at every point plagued with too much signal. The fluorescent [redacted] cannot be placed in the tower cab, for instance, because the level of the Xrays is such as to vaporize them before a significant readi

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All in all, the X-ray experiment is seen to be extremely difficult and by no means certain of success.

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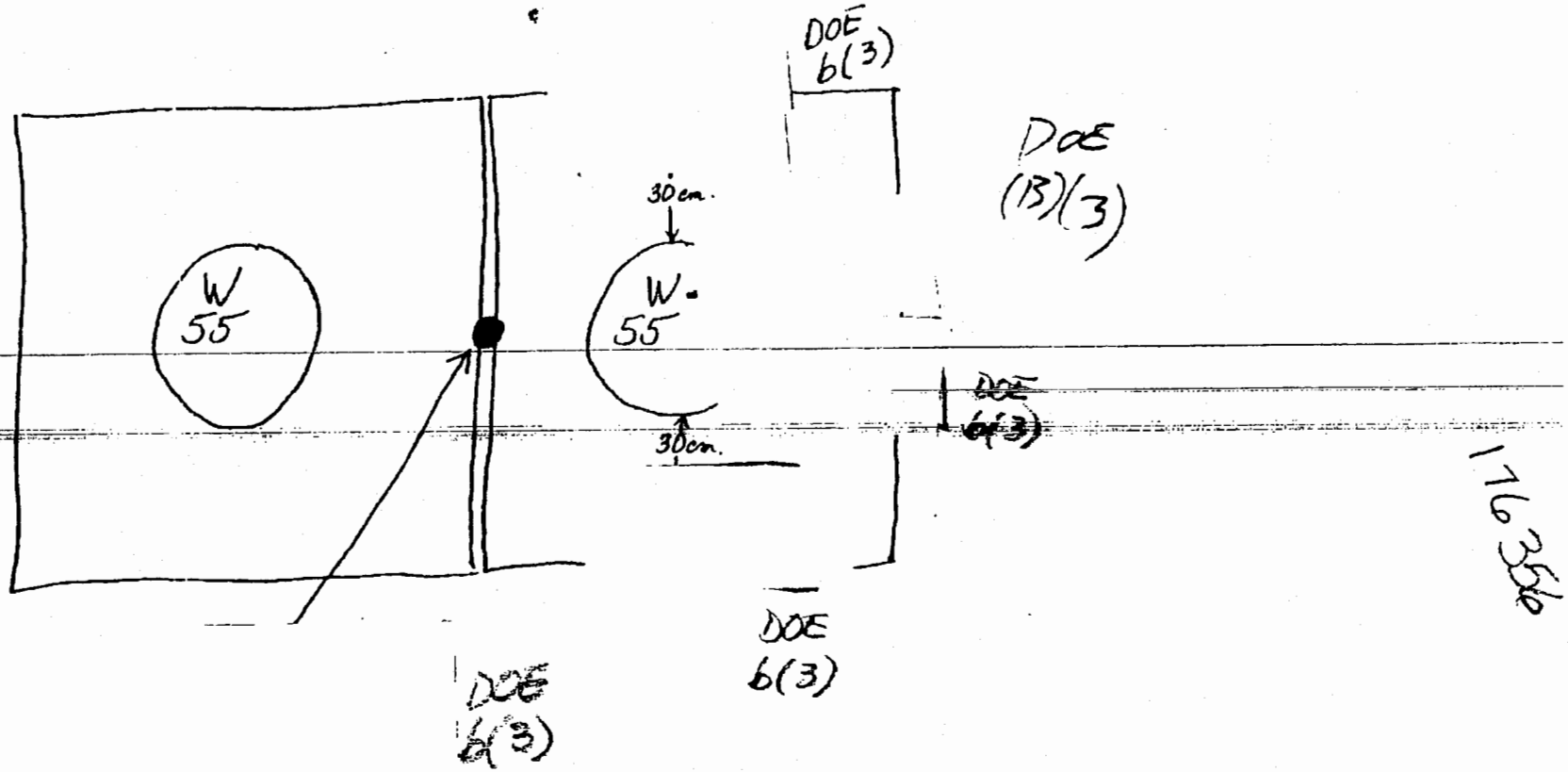

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