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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

RELATED CORRESPONDENCE

June 14, 1985

Joseph Gallo, Esq.
Isham, Lincoln & Beale
Suite 840
1120 Connecticut Avenue, N.W.
Washington, DC 20036

In the Matter of
Commonwealth Edison Company
(Braidwood Nuclear Power Station, Units 1 and 2)
Docket Nos. 50-456 and 50-457OL

Dear Mr. Gallo:

Enclosed please find the NRC Staff material concerning the calculation of the probability of occurrences for rail car explosion which you requested in the May 17, 1985 deposition of Mr. Charles M. Ferrell. Tr. 75-76. These are the work papers of Dr. Jacque Read dealing with construction permit stage analyses performed by the NRC Staff.

To the best of my knowledge these are the only work papers available.

Sincerely,

Elaine I. Chan

Elaine I. Chan
Counsel for NRC Staff

Enclosure: As stated

cc w/encl.: Board Members
C. Allen Bock, Esq.
Lorraine Creek

cc w/o encl.: Remainder of Service List

DS07

From information supplied by the applicant, U.S. railroads bore 7.3×10^{10} train-miles of traffic between 1917 and 1972, this number being a slight overestimate due to non-uniform reporting during the interval. This traffic experienced 46 explosive incidents, 24 of which occurred while the train was in transit and the remainder while loading and unloading. The overall explosion rate is therefore 5×10^{-10} per train-mile. Note, however, that the train-miles include passenger and freight traffic that have no explosive contents and the explosions include chemical and minor explosions which had only very localised effect. We may deduce, however, that the passage of 200 randomly chosen trains per year along a mile of randomly chosen track would have an apriori probability density of 10^{-7} per year for an explosion to occur there. The rail traffic adjacent to the Braidwood site differs from the overall

experience in that an explosion, should it occur, would involve 100 to 500 tons of TNT, and the stretch of track near Braidwood is, by virtue of its maintenance and inspection classification for express traffic, less likely to have any of the more common types of railroad accidents than an average stretch of track.

The applicant has computed the explosion probability density for Joliet Arsenal traffic passing the Braidwood site by three methods. The first method takes the overall railroad experience as described above, but weighted to emphasize recent years, and yields an estimate of 2.1×10^{-7} year^{-1}. The second method attempts to estimate the train-miles which contained explosives, and estimates 1.65×10^{-5} year^{-1}. The third method is similar to the second except that a weighted average was employed, and it yields 1.05×10^{-5} year^{-1}. The applicant has scaled all of these estimates

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by 0.036, this scaling factor being the product of three fractions claimed to represent advantages of Joliet cargoes over general cargoes:

1.) 0.135, the ratio of TNT-containing train-miles to total explosive train-miles. The use of this factor in methods two and three reduces the data base from total explosive train-miles to TNT train-miles, and is inappropriate in method one.

2.) 0.533, representing the "sensitivity factor" of flake TNT, or the fraction of flake TNT explosions that would occur under a variety of accident conditions such that general explosive cargoes would explode.

3.) 0.5, the fraction of all railroad explosions which were of large scale. The use of this factor is inappropriate, since it is known beforehand that the quantity of TNT in each Joliet shipment is significant.

(d)

All of the applicants' estimates are based on a site exposure of 150 train-miles per year, which is at the low end of the staff's estimated range of 100 to 500 train-miles per year, dependent upon military munition demand. Discarding the applicants' first method and the use of the third factor described as inappropriate above, the estimates become:

Method 2: 1.2×10^{-6} year^{-1}

Method 3: $8. \times 10^{-7}$ year^{-1}

The above are point estimates. They take no account for the high quality of the track adjacent to the Braidwood site, but they are subject to an increase of a factor of four or five if Joliet Arsenal should ever operate again at full war-time capacity. The reliability of the "sensitivity factor" of 0.533 is at least of a 50% confidence level, since at least one TNT boxcar derailment has occurred

without explosion. The applicant has repeated the staff's upper bound computation yielding a 95% confidence limit at less than or equal to 4×10^{-6} year^{-1}. The applicants first method indicates that the plant risk is most likely greater than 2×10^{-7} year^{-1}. We must conclude that the actual probability density lies between 4×10^{-6} and 2×10^{-7} and has a most probable value of about 1×10^{-6} year^{-1}

New information, supplied by the applicant, based on a survey of six months' of recent munitions shipment at Joliet Army Ammunition Plant. This survey indicates that only 17% of the munitions shipments leaving Joliet contain two or more box cars of flake TNT, but that a larger number of shipments are made than originally postulated. This result also shows that increases in munition tonnage during periods of warfare occurs through an increase in the average shipment size, rather than only an increase in the number of shipments; indicating a war time exposure to the Braidwood site approximately 2.5 times larger than peace time rather than the factor of 5 previously assumed. Since it is widely recognized that loading and unloading operations impose the greatest risks in munitions traffic, it is reasonable to assume that the six month period

surveyed by the applicant adequately represents expected future practice, since it minimizes the risk of accidents at Joliet Army Ammunition Plant within reasonable confines of cost and convenience.

From information submitted by the applicant, explosions occur in transit on domestic railroads at an average rate of 1.5 $year^{-1}$; and military munitions comprise an average of 2×10^7 train-miles per year. The applicant has surveyed the accident reports of the last 39 railroad explosions, covering a period of comparatively uniform reporting requirements, and has found that 6 of these explosions, or 15.4%, involved a significant amount of explosive. This is in approximate agreement with a staff survey of only the last several years experience, which indicated that about 11% of the reported "railroad explosive incidents" involved military munitions trains,

the remainder of the explosions involving small amount of diverse civilian explosive and incendiary materials. From this data it may be concluded that the observed overall explosion rate of military arsenal shipments is 1.2×10^{-8} per train-mile while in transit.

The peace-time exposure rate to the Braidwood Site is 350 train-miles per year, based on gross Joliet output since 1971, shipping practice during the first six months of 1974, and the inherent ability of the design to withstand single boxcar explosions. Assuming the applicants' claim that the plant is able to withstand the ~~simultaneous~~ detonation of ~~two~~ one boxcar of TNT, then the exposure rate can be reduced by that fraction of the shipments which may be expected to occur as fewer than ~~three~~ two adjacent boxcars. This

reduction result in an estimated exposure to damaging amounts of TNT of 60 train-miles per year during periods of low munitions production, and 150 train-miles per year during periods of high munitions production. From the gross munitions train explosion rate discussed earlier, these exposures lead to unacceptable explosions at expected rates of 7×10^{-7} and 18×10^{-7} per year, respectively, for the two production rates.

The gross munitions train in transit explosion rate includes accidents which have occurred to a large variety of weapons and military explosives. The applicant has submitted expert opinion that the particular munitions transported past the Braidwood Site are significantly less likely to explode inadvertently than other common military shipments. In support of this claim, a survey

of available railroad accident reports indicates that no flake TNT shipment has exploded in transit since 1916, although flake TNT has been involved in three major railroad accidents since then without exploding. Given the frequency of shipment of flake TNT, if it possessed the same likelihood of explosion as average munitions, it would have been most probable that two flake TNT explosions would have been observed during this period.

There is therefore a 75% confidence level that flake TNT is less than half as sensitive to explosion in a railroad accident, based on railroad statistics alone. [

to be filled in by Proctor

] ← NOC fill-in

Reducing the gross accident rate by those railroad accidents which will not cause large-scale high-order explosion of flake TNT, the expected rates of unacceptable explosions in the vicinity of the Braidwood Site may be estimated at 3.5×10^{-7} $year^{-1}$ for current Joliet production levels, and 9×10^{-7} for any period of expanded production.

Braidwood.

Fact — flake TNT appears to blow up as a stochastic process, without discernable precursor events.

Model — divide all flake TNT into 1 kg lots, such that if fate decrees that kilo to go it will propagate to surrounding TNT.

Assume ($\sim 10^8$ kg steady state inventory of flake TNT
(military ordnance exclusive of rockets + civilian explosives $\approx 3\text{-}4 \times 10^9$ /year)
(figure $\approx 1/16$. and 10% of cost goes through flake TNT, 1 year shelf life
or 20% " 6 mm " "

at 10^{-1} year^{-1} unexplained flake TNT explosions
$\therefore \sim 10^{-9}$ year^{-1} kg^{-1} = probability density for spontaneous explosion
5×10^5 kg / train
say 30 MPH train, 1.5 miles of sensitive track
$\therefore \sim 0.05$ hours / train of site exposure
say 200 trains / year or 10 hours / year
$\sim 10^{-3}$ of the time explosives bear on plant

5×10^5 kg/train 10^{-3} train 10^{-9} year^{-1} kg^{-1} = 5×10^{-7} year^{-1} for spontaneous explosion

note: (reciprocal metrics in explosive unit)

note 10^8 kg is very large 100,000 metric tonnes

$\therefore$

$P_x \geq 5 \times 10^{-7}$ year^{-1}

Shipments of explosives are limited to seven or fewer boxcars of flake TNT per train by the size of the loading facilities at the Joliet Army Ammunition Plant. Actual shipping practice can be affected by cyclical munitions needs, boxcar availability, railroad rate structure, safety considerations, and the division of work among the many Army arsenals, such that any number of boxcars of TNT within the possible range may appear in a given freight train on a given day.

The commonly accepted method of comparing damaging effects of explosions is the "scaled distance", which is defined as the distance in feet between the explosion and the structure in question, divided by the cube root of the weight of the charge in pounds of TNT equivalent. For comparison, the table below lists cumulative track length on which the explosion must occur to yield less than a given scaled distance, assuming a 1500 foot track-plant closest approach, and two possible shipment sizes, 10^6 lbs and 3×10^5 lbs.

Cumulative track length

Z	W = 10^{6} lbs.	W = 3×10^{5} lbs
15	0 feet	0 feet
20	2640	0
25	4000	2160
30	5200	3270

Railroad statistics collected by the applicant indicates that the ratio of all "explosives incidents" to miles of military munitions train traffic is 7×10^{-8} per train mile. Since the bulk of the "explosives incidents" reported do not involve large military shipments, this ratio must be reduced by the ratio of large military explosives accidents to total railroad explosions. The applicant and the staff agree that 0.135 is an apparently conservative estimate of this ratio. Past experience may then be interpreted to indicate a probability of 1×10^{-8} per train mile of large scale explosion in an Army ammunition plant shipment while in transit, based upon the judgement that materials transported past Braidwood are no more likely to explode than the average military ammunition train. The applicant in addition has supplied expert opinion that flake TNT is significantly less

susceptible to detonation than all other forms of common mining

explosives.

EXPECTED ACCIDENT RATE PER TRAIN-MILE

1. NON-OBSERVATION

1.6×10^{8} train-miles of TNT shipments with no applicable events

95% confidence rate $\leq$ 1.9×10^{-8}

50% confidence rate $\leq$ 6×10^{-9}

2 OBSERVATION PLUS DEDUCTION

$$\text{Rate} = \left[\begin{array}{c}\text{explosions per}\\ \text{explosive train-}\\ \text{mile}\end{array}\right] \times \left[\begin{array}{c}\text{fraction}\\ \text{applicable}\end{array}\right]$$

$$= \frac{\left[\begin{array}{c}\text{RR explosions}\\ \text{per year}\end{array}\right]}{\left[\begin{array}{c}\text{train-miles}\\ \text{explosives}\\ \text{per year}\end{array}\right]} \times \left[\begin{array}{c}\text{fraction}\\ \text{non-trivial}\end{array}\right] \times \left[\begin{array}{c}\text{sensitivity}\\ \text{factor}\end{array}\right]$$

$$= 6 \times 10^{-9}$$

80% confidence that sensitivity factor less than or equal to 0.5

EXPECTED ACCIDENT RATE PER TRAIN-MILE, λ

NON-OBSERVATION

1) ABOUT 1.6×10^{8} TRAIN-MILES OF TNT SHIPMENTS HAVE OCCURRED WITHOUT REQUIRED EVENT.

   $\therefore$ 95% CONFIDENCE, $\lambda \leq$ ~~[illegible]~~ $1.9 \times 10^{-8}\ TM^{-1}$

   $\therefore$ 50% CONFIDENCE, $\lambda \leq 6.2 \times 10^{-9}\ TM^{-1}$

OBSERVATION + DEDUCTION

2.) ABOUT 1.9×10^{9} TRAIN-MILES OF ALL CLASS A EXPLOSIVES HAVE OCCURRED {(FRACTION OF RECENT TRAFFIC)×(TOTAL 60-YEAR TRAFFIC)}

ABOUT 1.5 EXPLOSIONS/YEAR HAVE OCCURRED.

THREE RAILROAD ACCIDENTS HAVE HAPPENED WITHOUT REQUIRED EVENT.

$\therefore$ 80% CONFIDENCE THAT RATIO

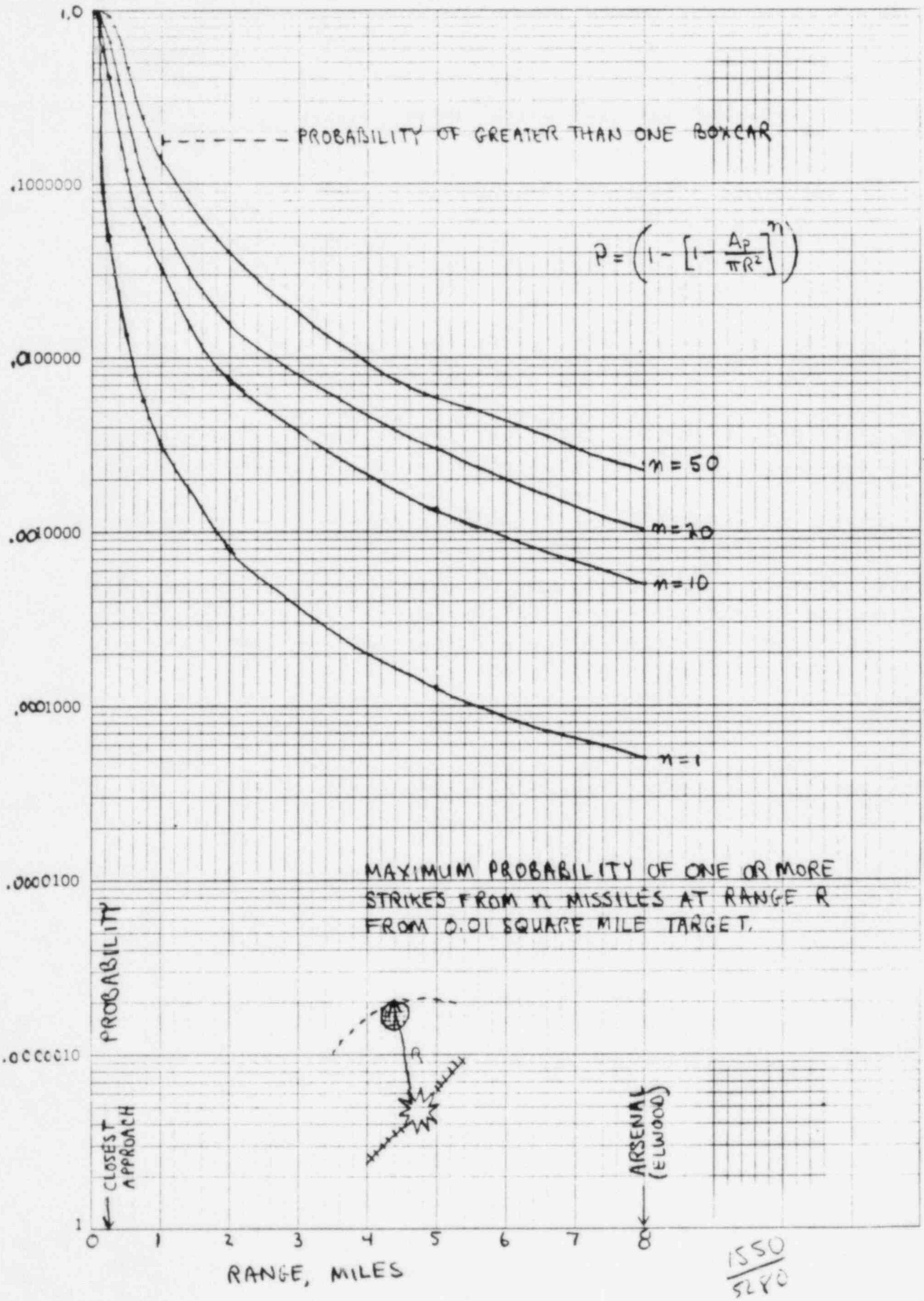
$$\frac{(\text{SENSITIVITY FLAKE TNT})}{(\text{SENSITIVITY ALL CLASS A})} \leq 0.5$$

$$\lambda \approx \frac{\left[\text{RAILROAD EXPLOSIONS PER YEAR}\right]}{\left[\text{CLASS A TRAIN-MILES PER YEAR}\right]}\left[\begin{array}{l}\text{FRACTION OF RECENT}\\ \text{RAILROAD EXPLOSIONS}\\ \text{THAT ARE NON-TRIVIAL}\end{array}\right]\left[\begin{array}{l}\text{ESTIMATED FRACTION}\\ \text{OF FLAKE TNT EXPLN.}\\ \text{PER CLASS A EXPLN.}\\ \text{GIVEN SAME INITIATION}\end{array}\right] =$$

$$\lambda \approx \frac{\left[1.5\ \text{year}^{-1}\right]}{\left[2 \times 10^{7}\ \text{TM year}^{-1}\right]}\left[0.15\right]\left[0.5\right] \approx 6 \times 10^{-9}\ TM^{-1}$$

↑ (average of ratio, ratio of averages)

MODEL DATE



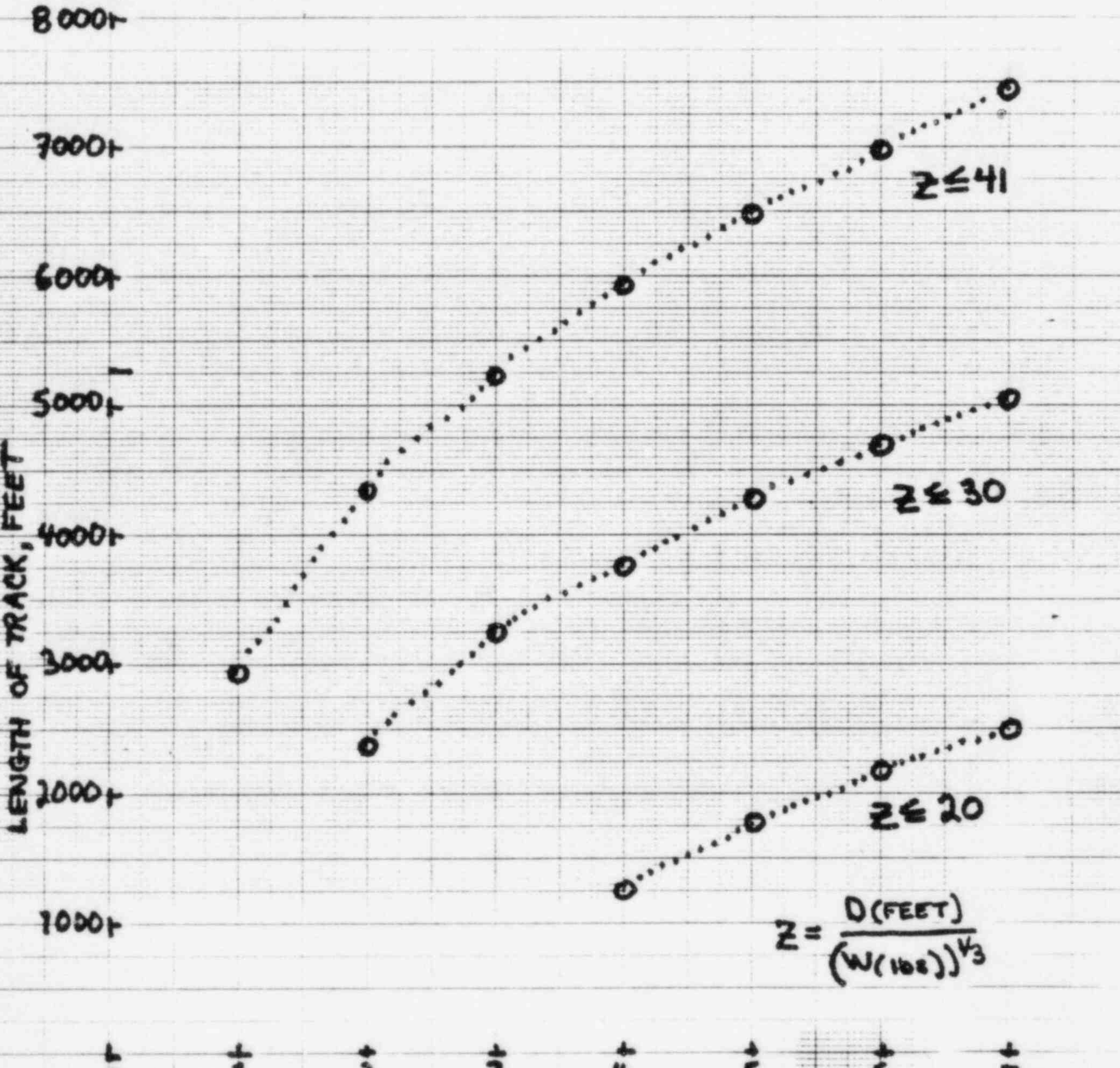
$\frac{1550}{5280}$

46 6463

K+E SEMI-LOGARITHMIC 7 CYCLES X 60 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A.

EXPOSURE PER TRANSIT AT BRAIDWOOD

LENGTH OF TRACK AT VARIOUS CUMULATIVE HAZARD LEVELS AS A FUNCTION OF NUMBER OF BOXCARS SIMULTANEOUSLY DETONATED



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METHODS OF COMPUTING BRAIDWOOD RAILROAD ACCIDENT PROBABILITY

METHOD	BASIS	APPLICANT PEACE	STAFF PEACE	STAFF WAR	COMMENTS
I	ALL TRAFFIC, ALL EXPLOSIONS	2.1×10^{-7} year^{-1}	—	—	TRAFFIC INCLUDES NON-EXPLOSIVES
II	EXPLOSIVES TRAFFIC 60 YEAR LINEAR AVERAGE, ALL EXPLOSIONS	1.65×10^{-5}	$\sim 2 \times 10^{-5}$	$\sim 1 \times 10^{-4}$	
	SAME, BUT TAKING CREDIT FOR ONLY TNT	6×10^{-7}	1.2×10^{-6}	5×10^{-6}	STAFF ASSUMES ALL JOLIET TRAFFIC EXPLOSIONS LARGE
III	EXPLOSIVES TRAFFIC, 60 YEAR WEIGHTED AVERAGE, ALL EXPLOSIONS	1.05×10^{-5}	$\sim 1 \times 10^{-5}$	$\sim 5 \times 10^{-5}$	
	SAME, BUT TAKING CREDIT FOR ONLY TNT	3.78×10^{-7}	$\sim 8 \times 10^{-7}$	$\sim 3 \times 10^{-6}$	SAME AS ABOVE

~ 1971 8.79×10^6 Appl. ≈ 0.133

(1.5)

$$\frac{(\text{Average railroad explosions / year})(\text{average fraction of railroad explosions due to military trains})}{(\text{average military train-miles / year})}$$

= average military shipment explosion rate / train mile

0.5

(above) × (fraction of accidents to military shipment which would cause explosion to assembled warheads but not to flake TNT)

(B) (train-miles of TNT traffic = $\frac{\text{total production of TNT}}{(\text{est'd shipment average size})(\text{average distance shipped})}$)

1.61×10^8 TNT train miles

for 95% confidence and no discontinuities

$\lambda = 2 \times 10^{-8}$ (95%)

$\lambda = 6 \times 10^{-9}$ (50%)

TETRYL trinitrophenyl methylnitramine

RDX cyclotrimethylene trinitramine

PETN pentaerythritol tetranitrate

TORPEX 41% RDX, 41% TNT, 18% Al

COMP B 110% blast, 80% energy, 130% brisance

PETN
Penta erythritol tetra nitrate

$C(CH_2NO_3)_4$

Amatol
80% to 50% NH_4NO_3
and TNT

TETRYTOL ← NNO_3 —
trinitro benzene

Pentolite PETN-TNT

Comp B is 60:40 Cyclotol
110% blast of TNT, 80% energy
130% brisance