DETERMINATION OF EXPLOSIBILITY OF OIL-AIR MIXTURES AND PREVENTION OF EXPLOSIONS BY ADDITION OF INERT GASES
(Item 16, frames 5-7)

In order to clarify the question of the explosibility of oil-air mixtures, a series of experiments was conducted on several products. The experiments were intended to yield information on conditions under which heavier oils in particular could participate in explosions by vaporization into an air stream and formation of oil-air mixtures.

Furthermore it was to be determined under what conditions these explosions could be prevented by addition of inert gases, such as carbon dioxide and nitrogen.

For this purpose an apparatus based on the following principles was constructed:

Through a flask half-filled with the experimental oil was conducted an air stream at a constant rate of 0.71 cubic feet per hour. The air was thus charged with oil vapor at various temperatures in accordance with the vapor pressure of the oil. The mixture formed in this manner was exploded in a heated refractory glass tube by means of a spark gap. It was thereby possible to vary the gas stream, the oil temperature and, consequently, the composition of the mixture, and the temperature inside the glass tube. In this way it was possible to define all conditions under which explosions occurred. Middle oil, fuel oil, and pitch distillate were tested.

I. Middle Oil

When the air flow rate was held constant at 0.71 cubic feet per hour an explosive mixture of gas with middle oil was reached at an oil temperature of 248 to 356 F. Neither at lower nor at higher temperatures were explosive mixtures obtained. According to individual measurements, the composition of explosive middle oil-air mixtures ranged from 0.0056 to 0.0079 pound of oil per cubic foot of air. If an average molecular weight of 150* is assumed for the middle oil, these values correspond to a middle oil content of 1.3 to 1.9 volume per cent, based on the total mixture. The oil-air mixtures were passed into the reaction chamber and were subjected to the action of a-c continuous or discontinuous spark discharges. Explosions occurred at a temperature of at least 365 F in the reaction chamber. Below 365 F, explosions were not obtained under any conditions; above 365 F explosions were readily obtained.

In order to investigate prevention of explosions occurring under known conditions, tests were conducted in the presence of carbon dioxide and nitrogen. It was found that the addition of 20 per cent carbon dioxide, based on the total air-carbon dioxide mixture (that is, 5 volumes of carbon dioxide to 20 volumes of air), was sufficient to prevent explosions. Larger proportions of nitrogen were necessary, under the same conditions, to prevent explosions; specifically, a nitrogen-air ratio of 1:1 was necessary, or, in other words, atmospheric oxygen had to be diluted from 20 per cent to about 10 per cent.

*According to a report by Dr. Ibing 6-4-38.

II. Middle Oil Containing 10 Per Cent Gasoline

A further experiment was conducted with the same middle oil to which 10 per cent of Welheim gasoline had been added. From this experiment it was found that the range of oil temperature at which the oil-air mixtures would explode was from 158 F to the initial boiling point of the middle oil-gasoline mixture. The corresponding oil content of the explosive mixtures was between 0.0199 and 0.0368 pound per cubic foot of air. If one assumes an average molecular weight of 110 for the gasoline preferentially vaporized at the temperature of the experiment, the corresponding concentration of combustibles is 6.5 to 12 volume per cent. The temperature of the reaction chamber was, as in Experiment I, at least 356 F. For prevention of explosions, 25 per cent carbon dioxide was necessary.

III. Fuel Oil

The experiment with fuel oil was conducted in the manner previously described. The oil temperature necessary for the saturation of the air in accordance with the vapor pressure of the fuel oil, lay between 500 F and the initial boiling point of fuel oil; that is, 0.00622 to 0.00934 pound of oil per cubic foot of air was necessary for an explosion. Conversion of these values gave, by assumption of an average molecular weight, for the fuel oil, of 220, about 1.0 to 1.5 volume per cent oil vapor in the mixture. Explosions occurred in the reaction chamber at and above about 356 F. For the prevention of explosions, 35 per cent carbon dioxide, based on the air added, was necessary. Explosions were prevented by the addition of nitrogen in amounts approximately equal to the amount of air in the gas mixture; that is a ratio of 1:1 was necessary, or the oxygen had to be diluted to 10 per cent.

IV. Pitch Distillate

These experiments were conducted as previously described. The following results were obtained:

The oil temperature necessary for explosion was 266 to 338 F; that is, about 0.0028 to 0.0062 pound of oil per cubic foot of air was necessary for the production of an explosive mixture. If one assumes an average molecular weight, for pitch distillate, of 200, these values correspond to an oil content of 0.5 to 1.1 volume per cent in an explosive mixture. The minimum temperature necessary in the reaction chamber was 356 F. Prevention of explosions was obtained by the addition of 15 per cent carbon dioxide to the air added.

V. Summary

It was found that explosions of the individual flammable oil-air mixtures were no longer observed when the mixtures contained from 15 to 35 per cent carbon dioxide. Such experimental results are dependent on the specific arrangement of the apparatus, on the specific conditions of ignition, and on the specific conditions in the reaction chamber etc. Consequently, they are not to be applied directly to all possible operating conditions. It can, nevertheless, be assumed that explosions cannot occur when the mixture in question contains more than 35 per cent carbon dioxide. Although nitrogen may be added to prevent explosions, considerably more than 35 per cent must be added; dilution of the oxygen present to not more than 10 per cent seems to be necessary.

EXPLOSION EXPERIMENTS WITH SEVERAL OILS

Product Investigated	Oil Content Necessary for Explosions		Temperature of Oil Necessary For Explosions, F	Lowest Temperature of Reaction Chamber Required for Explosion, F	CO_2 Necessary to Prevent Explosions, vol % of air-CO_2 mixture	N_2 Necessary to Prevent Explosion, vol % of air-N_2 mixture
	lb Oil/cu ft Air	Vol % Oil Vapor				
Middle Oil	0.0056-0.0079	1.3-1.9	248-356	356	20	50
Middle Oil + 10% Gasoline	0.0199-0.0368	6.5-12	158-IBP	356	25	-
Fuel Oil	0.00622-0.00934	1.0-1.5	500-IBP	356	35	50
Pitch Distillate	0.0028-0.0062	0.5-1.1	266-338	356	15	-

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SUPPLEMENTARY VOCABULARY

Translator's note: The following German words and abbreviations were not found in dictionaries available to the authors of this report.

German Word or Abbreviation	Suggested English Equivalent
Dampfloks	steam locomotive
Engpass	bottleneck
Jato	metric tons per year
Kastenkipper	mine car (bed has rectangular cross-section)
Korbbogen	catenary
LKw (Lastkraftwagen)	motor truck
Moto	metric tons per month
Muldenkipper	mine car (bed has approximately trapezoidal cross-section)
nachschalten	to connect (a unit of equipment) downstream (from another unit)
Nachschaltverdichter	after-compressor, booster compressor
PSe (Pferdestärke effektive)	effective horsepower
Stollenloks	locomotive for use in mines
Stuto	metric tons per hour
Tato	metric tons per day
vorschalten	to connect (a unit of equipment) upstream (from another unit)