SINCLAIR RESEARCH LABORATORIES, INC.

400 EAST SIBLEY BOULEVARD
HARVEY, ILLINOIS

September 8, 1960

U. S. Atomic Energy Commission
Washington 25, D. C.

4864

Attention: Division of Licensing and
Regulation, Isotopes Branch

Gentlemen:

We are hereby applying for a license to permit incineration of hydrocarbons containing low levels of particular isotopes in our plant boiler system.

Pertinent information, given on the attached sheets, is listed under the headings employed in the AEC release of September 10, 1958, entitled, "Information Required for Commission Approval of Treatment or Disposal by Incineration."

It will be noted that the original concentrations of the isotopes listed before dilution in the plant boiler system fuel storage tanks are low--of the order of 10^{-2} to 10^{-5} microcuries per milliliter. It will also be noted that the conservatively calculated airborne concentrations at the point where effluents leave the stack are well below the "unrestricted area" limits.

We believe that sufficient information is given for your review but, of course, will furnish any additional information which you may require.

Yours very truly,

SINCLAIR RESEARCH LABORATORIES, INC.

A. I. Snow

A. I. Snow
Chairman, Radioisotope Committee

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Isotopes Branch
Div. of L & R

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Attachment

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Information Required for Commission Approval of Disposal by Incineration

A. The type, quantity and chemical form of byproduct material to be incinerated.

Note: Each of the isotopes listed below is stored in a separate container.

Hydrogen-3

The tritium is contained in tritiated hydrocarbons. Maximum amount desired to be incinerated per year is 500 millicuries.

Carbon-14

The carbon-14 is contained in the form of hydrocarbons labeled with carbon-14. Maximum amount desired to be incinerated per year is 5 millicuries.

Cobalt-60

The cobalt-60 is contained in cutting oils used in experiments with radioactive cutting tool tips. It is in the form of very fine particles or possibly even in a solubilized form. Maximum quantity desired to be disposed of by incineration per year is 2 millicuries.

Iron 55 plus Iron 59

These isotopes are contained in lubricating oils used in engines in tests run with radioactive piston rings. They are contained in the form of very fine particles and also possibly in a solubilized form. Maximum quantity of iron-55 desired to be disposed of by incineration is 12 millicuries. Maximum quantity of iron-59 is 120 microcuries before disposal. The iron-59 is allowed to decay by at least 5 half lives before disposal.

B. Method of measurement of, or estimation of, the concentration of radioactive material in the effluent at the point it leaves the stack.

The means of incineration is the plant boiler system. This system contains a Babcock and Wilcox integral furnace boiler of the water tube type. It contains high pressure (25 to 250 psi) atomizing burners. This furnace operates with a minimum of 50% excess of air over that needed for complete combustion of the fuel with at times an air excess of 200%. Burning rates range from 1000 gallons per day to 6000 gallons depending on the season of the year.

There are two 30,000 gallon storage tanks used to service this furnace system. Inventory is kept above 40,000 to 50,000 gallons. For purposes of this application it will be assumed that all liquid dilutions will be made in a fuel volume of about 20,000 gallons, or 8×10^7 cc which is a safe minimum figure. The material to be incinerated will be pumped into the storage tank from drums while the storage tank is being loaded to insure good mixing. The material to be incinerated will be pumped through a filter to remove any possible sludge or particulate matter. The filter will be sent to Oak Ridge for disposal.

In order to calculate the concentration of radioactive material at the point where it leaves the stack it is necessary to determine the volume change when one volume of liquid hydrocarbon is burned. The calculation of change in volume on combustion follows.

The hydrocarbon fuel may be regarded as having the formula $(CH_2)_n$. On burning the following chemical reaction occurs

$$(CH_2)_n + 3/2\ n\ O_2 \longrightarrow n\ CO_2 + n\ H_2O$$

A mole of carbon dioxide is formed for each mole of carbon atoms originally present in the liquid. At standard temperatures and pressures one mole of carbon dioxide will occupy a volume of 22,400 cc. Taking the conservative value of 0.7 gm/cc for the density of the fuel burned then every 14 grams or 20 cc of liquid will form 22,400 cc of CO_2 gas, 1 cc of liquid hydrocarbon will form $\frac{22,400}{20}$ or 1120 cc of CO_2. Since air consists of 80% nitrogen then for every volume of oxygen used 4 volumes of nitrogen will be carried in the system. Also since at a minimum a 50% excess of air is used over that needed for complete combustion this excess air also introduces a dilution factor. The total amount of gas emitted from the stack at the point where it leaves the stack is therefore

$$3/2 \left(4 + \frac{5}{2}\right) \quad 1120 + 1120 = 10\text{-}3/4\ (1120) = 12040 \text{ cc}$$

Therefore 1 cc of liquid hydrocarbon incinerated will yield 1.2×10^4 cc at the stack.

We now consider the concentration of each isotope, in turn, at the point where it leaves the stack.

1. <u>Tritium</u>. The maximum concentration of tritium activity in the storage tank system is to be set at 10^{-4} microcuries/ml. This liquid concentration leads to a maximum tritium concentration in effluent at the point where it leaves the stack of 8.3×10^{-9} μc/ml. This number is to be compared with Part 20, Appendix B, Table II, Column 1, "unrestricted area" limit of 2.5×10^{-6} μc/ml. The maximum tritium concentration to be expected is 0.3% of this limit.

It may be of interest to note that the maximum concentration of tritium in the water produced by combustion is 10^{-4} μc/ml which is well below the "unrestricted area" limit of 1.6×10^{-2} μc/ml for tritium in liquid water.

The concentration of tritium in the hydrocarbons to be added to the 20,000 gallons in the tank will be determined by means of liquid scintillation counting on equipment available at our laboratory. Once this concentration is known it is a simple calculation to determine the maximum volume to be added to the boiler fuel for incineration.

$$\text{Maximum volume to be added in cc} = \frac{(8 \times 10^{7})\ 10^{-4}}{\text{specific activity of material added to boiler fuel in } \mu c/ml}$$

$$= \frac{8000}{\text{specific activity of material incinerated } (\mu c/ml)}$$

$$= \frac{8}{\text{specific activity of material incinerated } (mc/ml)}$$

Carbon-14. The maximum concentration activity of carbon-14 activity in the storage tank is to be set at 10^{-5} μc/ml. This leads to a maximum concentration at the point where effluent leaves the stack of 8.3×10^{-10} μc/ml. The "unrestricted area limit" is 5×10^{-8} μc/ml. The maximum carbon-14 concentration expected in the effluent at the point where it leaves the stack is 1.6% of this limit. It may be noted that the newly proposed limit for C-14 in CO_2 in air is 1×10^{-6} μc/cc so that the CO_2 concentrations at the stack exit are .08% of this newly proposed limit.

The carbon-14 specific activity in the material to be incinerated before dilution will be determined by liquid scintillation spectrometry in equipment available in our laboratory. Following a computation similar to that given for tritium above,

$$\text{maximum volume to be added in cc} = \frac{800}{\text{specific activity in } \mu c/ml \text{ of material added to boiler fuel}}$$

<u>Cobalt-60</u>. The maximum concentration of cobalt-60 activity in the storage tanks is to be set at 3×10^{-7} μc/ml. This leads to a maximum concentration of effluent at the point where the effluent leaves the stack of 2.5×10^{-11} μc/ml. The "unrestricted area" limit for Co-60 in air is 8×10^{-7} μc/ml so that the maximum concentration expected is .003% of this present limit.

The cobalt-60 concentration in the cutting oils before further dilution in the fuel storage tanks will be determined by use of a sodium iodide (thallium activated) scintillation detector available in our laboratory.

$$\text{Maximum volume to be added in cc} = \frac{24}{\text{specific activity of material added in } \mu\text{c/ml}}$$

<u>Iron-55, Iron-59</u>. The maximum average concentration of iron-55 activity in the storage tank is set at 10^{-5} μc/cc leading to a maximum Fe-55 concentration in the effluent at the point where it leaves the stack of 8×10^{-10} μ c/cc. In the nuclear reactor three times as much Fe-55 activity is originally produced as Fe-59. Allowing the Fe-59 to decay through at least five half-lives before disposal leads to a maximum Fe-59 concentration in the storage tank of close to 10^{-7} μ c/ml. The maximum Fe-59 concentration at the point where it leaves the stack is therefore 8×10^{-12} μc/ml. The Fe-55 maximum average concentration in the effluent is 1.3% of the "unrestricted area limit" in air, of 6×10^{-8} μc/ml. The Fe-59 maximum average concentration is 0.53% of the "unrestricted area limit" of 1.5×10^{-9} μ c/ml.

The method of determining concentrations of Fe-55 and Fe-59 in the engine oils before dilution is to make use of the data obtained during the wear tests. Counts are taken continuously by means of a scintillation detector during the test and also at the end of the test period. The total volume of oil in the system is known, the volume of the counting chamber and efficiency for counting Fe-59 are also known. Fe-55 is not detected because its rays are absorbed in the material around the counter. At the time of arrival of the rings filings are taken from the rings and counts are taken at time intervals to follow the decay of the rings.

With the data available the milligrams of wear products present in the whole oil system are calculated for each test and recorded. Knowing the specific activity of the rings in terms of Fe-59 and Fe-55 content one can use the number of milligrams to compute the Fe-55 content in the total oil volume.

Example: Immediately after activation a ring had an Fe-55 activity of 37.5 millicuries. Ring weight was 31 grams. Total volume of the oil system in the engine is 11500 ml.

Therefore Fe-55 concentration in this oil per milligram of iron contained in the oil system is

$$\frac{37.5 \times 10^3}{(31 \times 10^3)(11500)} = 1.05 \times 10^{-4} \mu c/ml$$

For 10 mg of wear in the system this concentration of Fe-55 is $10^{-3} \mu c/ml$. Fe-55 has a 2.94 year half life. Fe-59 has a 45.1 day half life.

The concentration of Fe-59 in the oil is equal to

$$\frac{1.05 \times 10^{-4}}{(3)(2^n)} = \frac{3.2 \times 10^{-5}}{2^n}$$

where n is the number of half lives. Its concentration can also be determined directly by use of the counts obtained at the time of the test and using the known efficiency of the counting system.

We have computed the average number of milligrams in the 11,500 cc oil system by taking the average of data from 148 tests. The average number of milligrams per test was 8.9 milligrams. This leads to a concentration

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of Fe-59 of around $9 \times 10^{-4}\ \mu c/ml$.

Maximum volume to be added to boiler fuel in cc =

$$\frac{8 \times 10^{7}\ \ 10^{-5}}{9 \times 10^{-4}} = \frac{800}{9} = 9 \times 10^{5}\ cc$$

Since the test oils are put into numbered drums one can compute average concentrations for any series of tests and by a computation similar to that given above can insure that maximum concentrations are not exceeded.

C. Methods of control to insure that particulates and concentrations of radioactive materials are not released which could result in exposures of individuals in excess of the levels set forth in the AEC's "Standards for Protection Against Radiation," Part 20.

The methods of calculation to insure that the maximum concentrations of effluents at point of leaving the stack are given under B. These calculations yield a maximum volume for each isotope to be added to the fuel oil in the storage tanks. Written orders will be given to the pumper involved stating the identity of the waste oil containing drums to be incinerated. His following these orders will be checked. If the maximum volumes given by the calculations are not exceeded then the calculated maximum concentrations at the stack effluent point will not be exceeded.

The question of particulates is next to be considered. In regard to tritium and carbon-14 there is extremely little likelihood of their appearing in particulate matter since the total amount of carbon particles produced in the boiler furnace is an extremely small percentage of the fuel weight that is burned.

In regard to cobalt-60, and Fe-55, Fe-59 one must consider the possibility that there is concentration of these isotopes in a small volume that is released from the stack at one time.

The manner in which the boiler is operated make this possibility extremely unlikely. In the operation of this boiler particulate matter is blown out of the stack twice per day on a regular schedule by means of compressed air. Although the volume of soot formed is small this procedure is followed to insure that the boiler tubes stay clean and thus operate at maximum efficiency. Heavier particles settle to an area in the bottom of the furnace well below the burners. After a year's operation the volume of this heavier material is about 2 cubic feet indicating that the operation is fairly clean. It is also of some interest that the literature on oil fired furnaces indicates that ash particles are of the order of 0.4 microns (4×10^{-5} cm) in diameter.

The twice-per-day soot blowing procedure insures that no large concentrations of radioactive materials can build up on the tubes.

If one imagines the extremely unlikely situation that all of the activity released into the stack in 12 hours is released on one particle and if one used the maximum burning rate of 6000 gallons per day then for cobalt-60 at the maximum concentration to be used this particle would contain 2.8 microcuries, for iron-55 the number would be 118 microcuries and for iron-59 one microcurie. These numbers can be compared with the body burden limits in the newly proposed AEC regulations of 10 for Co-60, 1000 for Fe-55, and 20 for Fe-59. Because of the controls on total quantities of radioactive materials in the system at one time, because of the low concentrations of these materials in the system, and because particulate matter is not allowed to build up in any appreciable quantity on the furnace walls it appears extremely unlikely that any particulates or concentrations of radioactive materials could be released which would result in exposure of individual in excess of the levels set forth in part 20.

D. The height of the incinerator stack, expected dilution factors (if necessary), and the height of and distance to buildings in the surrounding area.

The height of the incinerator stack is 43 feet. A plot plan is attached giving the relative locations, heights of adjacent buildings and other pertinent details.

In regard to dilution factors it should be noted that all air concentrations are given in terms of maximum concentrations of radioactive material in the effluent where it leaves the stack. For all of the isotopes these calculations show that the concentrations are well below any pertinent limits. In actual practice a great deal of further dilution will of course occur as the gas leaves the stack. These dilutions will decrease the concentrations from a very low level to an even lower level.

E. The procedures which will be followed to prevent overexposure of personnel during all phases of the operation--particularly the instructions given to the persons handling the combustibles and the ashes.

All the material to be incinerated is contained in hydrocarbons. This material is in water insoluble form. Cobalt-60 in cutting oils is present at concentrations of 10^{-4} to 10^{-5} μc/ml. Fe-55 is present at concentrations around 10^{-3} μc/ml. Fe-59 concentrations are around 10^{-5} μc/ml. Carbon-14 concentrations are in the vicinity of 2.5×10^{-2} μc/ml. Tritium concentrations are always below 10^{-2} μc/ml.

Since all of these waste materials contain the radioactive materials, before any further dilutions, in such low concentrations in water insoluble form there is little, if any, danger of over-exposure of individuals handling these materials. We nevertheless will monitor the drums containing gamma emitting materials for external radiation and will issue film badges to individuals handling these drums.

The instructions to the person handling the combustibles involve following standards of cleanliness, avoiding spills and the like. The instructions also include the use of a filter in the line used to pump from the waste drums into the fuel storage tanks. The filter is to be handled with gloves and turned over to authorized personnel for further disposal.

In regard to the ashes, they are shoveled from a location in the bottom of the furnace to which entrance is gained by opening doors located at the bottom of the furnace. The ashes will be monitored by a survey meter before and after shoveling. No shoveling is to commence without monitoring. The shovel will be furnished with a respirator to avoid possible ingestion of any of the ashes. The ashes will be placed in a marked drum.

Since ingestion is avoided by the use of the respirator the next point is the question of external radiation. In these calculations it is assumed that all of the gamma emitting isotopes incinerated per year remain in the ashes. The maximum values are used. Since as is shown below even with this extreme calculation external radiation hazard is small, then for the actual situation the external radiation hazard will be even less than the small dose calculated.

If all the maximum amount of cobalt-60 were incinerated (2 mc) and if it all stayed in the ashes and acted as a point source with no self absorption the radiation intensity at 1 meter would be 2.7 mc/hour. Assuming it is a cylindrical source, which is closer to the actual case, 2 feet in diameter and 1 foot then one obtains a dose rate of the order of 0.7 mc/hour from the cobalt-60 at 1 meter. The gamma rays from Fe-55 are very easily absorbed because of the low intensity (5.9 kev). One would be affected only by the surface of the ashes containing Fe-59. The dose expected at one meter from the ashes would certainly be less than 1 mr/hour. The radiation dose from Fe-59 on the same basis is around 0.02 mr/hour at 1 meter from a source 2 feet in diameter and 1 foot high.

The time of shoveling is about 1 hour. Even if all of the radioactive materials present in the system were 100% retained the radiation exposure of the shoveler is very slight. Maximum exposure would be expected to be of the order of 2 milliroentgens. Actual exposure due to a variety of factors should be much less than even this small number.

F. The method for disposing of contaminated ash.

The contaminated ash removed from the bottom of the boilers will be placed in marked drums and then sent to Oak Ridge for disposal. The thin layer of soot around the tubes above the fire zone is washed into the sewer system. Much of this material dissolves and the remainder is easily dispersable in water.

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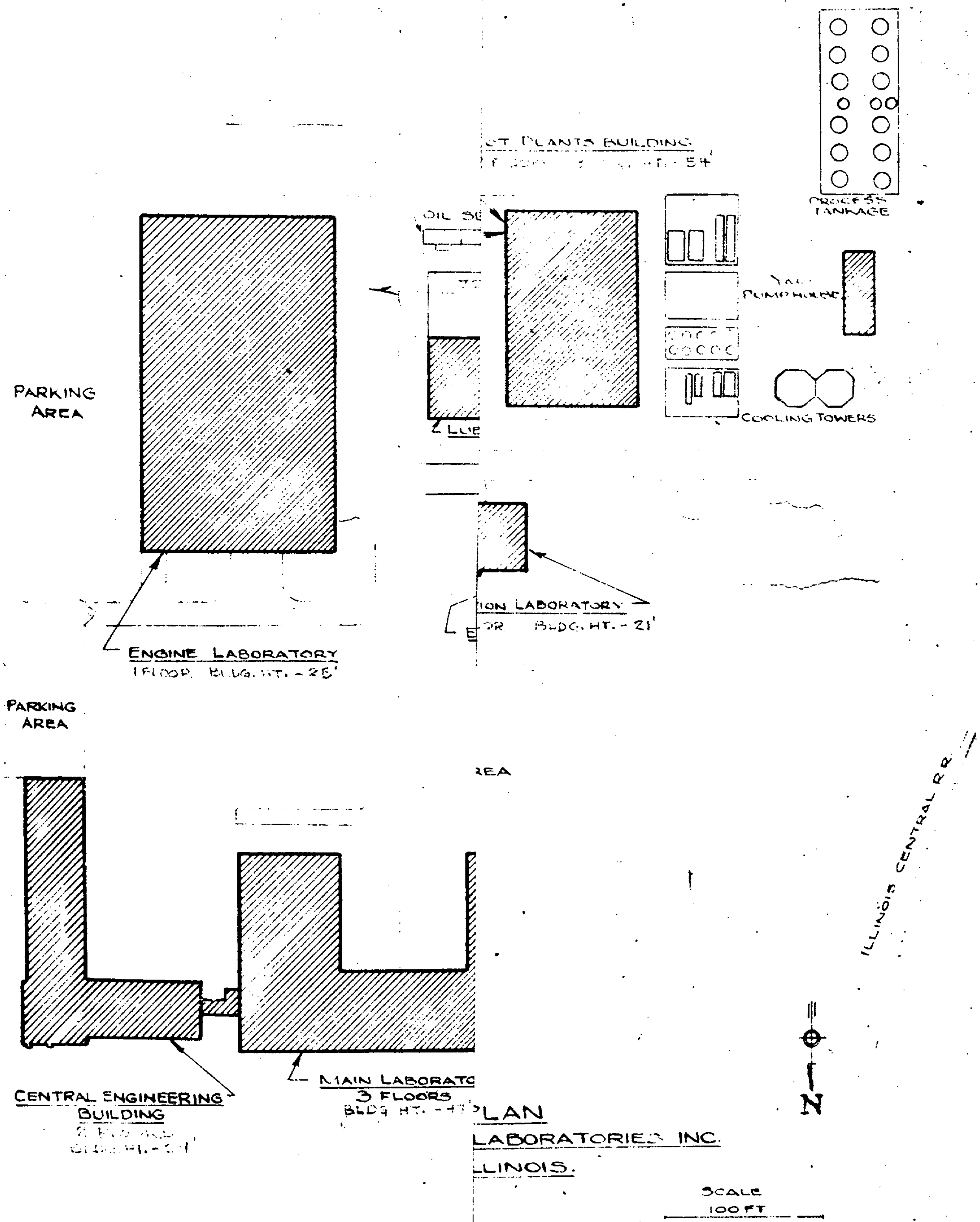

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