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ICS DIVISION

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REPORT FOR MONTH ENDING JANUARY 31, 1946

L. W. Nordheim

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Summary

The work on the heterogeneous enriched pile is progressing satisfactorily. The lay out of the whole installation is to a large extent determined by the experimental facilities. A series of discussions was held with the design group of the technical division and the instrument is gradually acquiring a definite shape.

Studies have been made of hot spots under spacers in the assemblies, of the shielding requirements and of the Xenon effect. It has been found that ribs or pimples on the plates will not cause excessive troubles. It is proposed that W type inserts be made in a concrete shield in order to permit the bringing of apparatus to a minimum distance from the neutron source.

The Xenon effect will necessitate very careful planning of operations, schedules and arrangements of experiments. In a high flux pile the Xenon concentration is limited by the self destruction due to neutron absorption at constant operation. After a shutdown or reduction of power level the concentration will increase sharply due to the continued production by the parent iodine in absence of this mechanism for removal. Every shutdown will, therefore, lead to a fairly long dead period of the pile.

The critical experiments on inhomogeneous mixtures will be started early in February. It is also expected that a controls and instrumentations group can be set up in the near future.

The following points may be mentioned in connection with the current physics program.

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The pile oscillator has been tested with various samples and has proved to be a reliable instrument. Using the proximity effect, cross sections as small as 0.1 mm^2 can be measured with a probable error of about 20%. With hydrogenous materials a negative effect (increase of neutron intensity if the absorber is near the detector) is observed due to greater effectivity of slowed down neutrons in a borondetector. The fast oscillator for measuring of pile constants is now ready for tests.

The apparatus for photoneutrons from fission products has now finally been completed and is ready for operation.

The double crystal spectrometer has been further developed.

With respect to C^{14} plans have been initiated to expand future production by the replacement of the present liquid factory by batch processing of calcium nitrate slugs to be irradiated in the reflector.

Work on several nuclear physics problems has been resumed or initiated. Among these are the study of gamma energies per beta ray by integration in an aluminum block, the search for long range alphas from plutonium, and plans for measuring the life time of neutrons. The latter work will probably grow into a major undertaking of fundamental importance. Plans for the pilito as precision instrument have also been continued.

In the current period Drs. S. DeBenedetti, W. M. Preston, and C. D. Goodman have joined our staff as senior physicists.

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Physics Section I

A. H. Snell, Section Chief

Total technical personnel (including supervision)....8 (this period)

Problem Assignment Number	Subject	Status	Percentage of Section Manpower Report Per.	Next Per.
PX1-7	C^{14} Production	Active	30	25
PX6-4	Neutron Temperature in Pile	Active	12	0
PX8-1	Gamma Ray Spectra	Inactive	0	0
PX8-2	Photoneutron Sources	Inactive	0	0
PX14-1	Criticality of Vessels	Active	16	0
163-X39P	Service Flux Measurements	Active	12	5
PX8-4	Gamma Energy per Beta	Active	15	30
PX5-15	Controls	Inactive	0	00
	Critical Experiments	Active	5	35
	Neutron Decay	Active	10	5
		Total	100	100

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PX1-7 - C^{14} Production - (Norris, Arnette, Schuler)

The factory lost four days' production last month through pump trouble. The effect of warming the solution was investigated; the cooling was turned off, and the solution allowed to rise to its equilibrium temperature, which was about 40°C. During 24 hours of this, a much larger amount of barium carbonate precipitate was formed than during a similar period at lower temperature. The cooling was then turned on again, and the yield of precipitate returned to normal. The large precipitate has not yet been assayed for C^{14}.

A decay curve has been obtained of the activity of the gas that emerges from the extraction train. Some C^{14} activity is present -- an indication that we are losing a little of our product. There are also apparently activities with half-lives of (1) several hours, and (2) about 16 minutes. These do not agree with anything that might reasonably be expected, but it is doubtful if we will have time to identify them.

The preparation of C^{14} standards is proceeding.

The possibility of increasing the Clinton Laboratories production of C^{14}, as mentioned in last month's report, was laid before the Isotope Committee. It was generally felt that there was sufficient uncertainty about Hanford plans to justify an independent start at Clinton. The Technical Division has accordingly undertaken to can about 7000 slugs of calcium nitrate and the liquid factory will probably be removed in two or three months. Production from the canned material will probably start about July.

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We have about 40 millicuries of C^{14} on hand at present, including several unassayed samples.

PX6-4 - Neutron Temperatures in Graphite - (Branch)

Pyrex plates of dimensions 2" x 3" x 0.040" have been received from Corning Glass Works and are being used as absorbers in the neutron temperature measurements made in the standard pile. Several transmissions have been measured, but the corresponding temperatures have not been calculated, pending the calibration of the absorbers in a mono-energetic neutron beam.

Transmissions have been measured in Slot 3 (z = 34 cm) for graphite temperatures of 4° and 10° C and in Slot 12 (z = 125 cm) for a graphite temperature of 3° which indicate a lowering of neutron equilibrium temperature with increasing distance (z) from the Ra-Be source. The following transmissions of thermal neutrons have been measured this month:

SLOT	Z	GRAPHITE TEMP.	TRANSMISSION
3	34 cm	4° C	0.348
3	34 cm	10°	0.354
12	125 cm	3°	0.333

The increase in transmission apparent as the graphite temperature goes from 4° to 10° at Slot 3 may be due to a dependence of neutron temperature on graphite temperature; however, the probable errors have not been computed yet and the statistical error may be larger than the difference observed.

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Gold absorbers of variable thickness are being fashioned from 0.005" Au foil and will also be used for measurements of the transmission as a function of absorber thickness.

PX8-2 - Photoneutron Sources - (Barker, Sternberg)

The photoneutron yields from Gallium 72 and beryllium in deuterium have been measured. The results are as follows:

$$\alpha \sigma_{Be} = 1.85 \times 10^{-28} \text{ cm}^2$$
$$\alpha \sigma_{D} = 2.50 \times 10^{-28} \text{ cm}^2.$$

where α is the number of effective (i.e. 2.25 Mev) gamma quanta emitted per disintegration beta.

PX8-4 - Gamma energy per beta - (Barker, Sternberg)

Active work has been resumed in preparing the apparatus for these measurements. A means of inserting sources into the aluminum block has been worked out. The ionization chamber - FP54 carriage has been built. The circuit has been assembled. At present work is in progress on the FP54 amplifier. When the apparatus is made to settle down and give dependable readings, the gamma energy emitted by Sodium 24 and Gallium 72 will be measured, and the results will be used in conjunction with the photoneutron yields measured inthe work for Problem Assignment PX8-2.

PX14-1 - Criticality of Vessels - (Snell)

Considerable time has been spent on the two reports covering this work, viz. MonP-47 and MonP-48.

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Neutron Decay - (Saxon, Shrader, Snell)

A metal evaporating outfit is being assembled. The design of the proton-collecting system is being studied by the stretched-rubber-and-ball-bearing technique. The vacuum system has been mostly designed.

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Physics Section II

A. M. Weinberg, Section Chief

Total Technical Personnel (Including Supervision).....7(this period)

Thermal Utilization in Heterogeneous Pile (Scalettar)

Because of the lattice structure of the new pile, the parasitic absorption in the P-9 will be somewhat greater than if the pile had been homogeneous. In the following table are given f, the thermal utilizations (fraction of neutrons absorbed in assembly) d, the ratio of average neutron density in the P-9 to average density in the assembly, and f_o, the thermal utilization if the assembly material were spread uniformly:

Concentration (grams 25/li)	f	f_o	d
1	.958	.968	1.309
2	.980	.984	1.287
3	.986	.989	1.275
4	.990	.992	1.267

The present plan is to use a lattice arrangement (15 cm triangular pitch) corresponding to about 3 grams of 25 per liter.

Diffusion Length in Heterogeneous Pile (Scalettar, Weinberg)

The dimensions of the new pile are comparable to the diffusion length in P-9 and are not very much larger than the lattice dimensions. There is therefore some question whether the usual macroscopic theory of the homogeneous pile is applicable. In particular, the formula for the pile diffusion length, $L^2 = (1 - f) L_1^2$, where L_1 is the moderator diffusion length, must be re-examined.

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Calculations of the diffusion length in a lattice were made by Plass (CP-992) for a spherical lattice, but his results are not readily applicable to the present case. We have found that for a slab pile of infinite length but finite width and breadth, the pile diffusion length can be expressed in a fairly simple closed form. Using this formula we find that the diffusion area in the enriched pile is about 4% greater than the value usually calculated.

Hot Spots Under Ribs in Enriched Pile Assemblies (Weinberg)

If ribs or pimples are used to maintain the separation between adjacent plates in the enriched pile, heat transfer coefficients will be lowered in the vicinity of such obstructions and hot spots will develop there. The temperature rise under such spots has been calculated by Karush. His results indicate that under the conditions prevailing in the proposed pile, the film drop under a 2 mm. wide rib will be 35% higher than the normal film drop. Under a 2 mm. diameter pimple the increase is only 15%. Neither of these temperature rises seems excessive, and therefore we are recommending the use of spacers.

Xe Poisoning in Pile (Abelson)

When the enriched pile is shut down, Xe^{135} will continue to be produced by the decay of I^{135} but it will not be destroyed by neutron capture. As a result the density of Xe^{135} will rise very markedly. The consequent reactivity loss means that the pile will be non-reactive for a fairly long time after shut down. In an enriched pile run at high flux the rise in Xe density is very much greater than the values calculated by Friedman for an unenriched pile.

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In the following table we list, for various fluxes, the ratio of maximum to steady state Xe concentrations and the time after shutdown at which the maximum occurs.

Flux	$Xe_{max.}/Xe_o$	t(hours)
1×10^{13}	1.3	6.7
5×10^{13}	3.0	11.1
1×10^{14}	5.1	11.1
2×10^{14}	9.7	11.1
4×10^{14}	22.4	11.1
10×10^{14}	47.0	11.1

The maximum flux in the new unit is about 4×10^{14}. The Xe will therefore reach a concentration 22 times its equilibrium value at this high flux. It will return to its equilibrium value about 3 days after shutdown. This is the order of time which will be needed to regain original reactivity after an accidental scram.

Pilito Temperature Coefficients (Soodak)

The pilito being considered is a small pile containing $\sim$ 600 gm of U^{235} homogeneously embedded in $\sim$ 15 liters of a hydrogen containing plastic such as polyethylene. The total absorption cross-section of the pilito is $\sim$ 1000 cm^2 of which about 300 cm^2 are due to hydrogen and 700 cm^2 to U^{235}. The reactor is surrounded by a graphite reflector which in turn is surrounded by some shielding.

The main purpose of the pilito is to measure the absorption cross-sections of rare isotopes such as the fission products. It is important, for these experiments, to know the properties of the pilito as regards to stability. For this reason, the temperature

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coefficient of the pilito has been estimated.

Since both the absorption cross-section and the density decrease with increasing temperature, the reactor has a negative temperature coefficient. On the other hand, the decrease of density in the reflector is unimportant while the decrease of its absorption cross-section improves the reactivity. Thus the temperature effect of the reflector is positive.

The results of the calculation are as follows:

$$\frac{\delta k_{eff}}{\delta T} \approx -2.5 \times 10^{-5} \text{ per}^{\circ}\text{C} \quad \text{for the Reactor}$$

$$\frac{\delta k_{eff}}{\delta T} \approx +0.5 \times 10^{-5} \text{ per}^{\circ}\text{C} \quad \text{for the Reflector}$$

The pilito as a whole has then a negative temperature coefficient and would be a very steady pile, if only temperature considerations were important. However, at the low fluxes present in the machine statistical fluctuations may seriously hamper measurements which require a steady flux. In the above calculations, the effect of the presence of air (nitrogen is a neutron absorber) has been neglected. This effect is rather small, however, and would represent a correction to the above values of only several percent.

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Physics Section III

E. O. Wollan, Section Chief

Total technical personnel (including supervision).....10 (this period)

Problem Assignment Number	Subject	Status	Percentage of Section Manpower Report Per.	Next Per.
PX6-1	Pile Oscillator	Active	20	20
PX10-8	Crystal Spectrometer	Active	20	20
PX10-16	Characteristics of Fission Products and Neutron Induced Activities	Active	10	10
PX10-18	Short Half-Life Gamma Energies	Inactive	0	0
PX10-19	Capture Gamma Energies	Active	20	20
PX10-3	Cloud Chamber Studies	Active	20	20
	Writing		10	10
		Total.....	100	100

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PX10-19 - Capture Gamma Energies - (Koch, Willard)

Photography of the electron tracks produced by the neutron and gamma background near the pile wall is underway and an analysis of the character of this background in terms of number and energies is being made. These tests will prove the need for shielding. A new camera is well towards completion in the shop and a current regulator circuit for the magnetic field coils has been made by the electronics group.

PX6-1 - High Speed Pile Oscillator* - (Koch, Moak)

An air turbine with a stainless steel top and a graphite stator has been made to successfully operate at a speed of 100 cps and at the pile temperatures and conditions required of the fast oscillator. Some slight improvements in stability of operation were made possible by an analysis of the top fundamentals carried out at the beginning of this period. However, the main contribution to making a working unit is attributed to the selection of correctly treated materials with suitable properties.

Although the stainless steel top is almost black to neutrons, which will reduce the neutron signal obtainable, the present unit will be installed in the pile. Cadmium quadrants are now being attached to the top surface of the rotor and rechecks of the turbine's operation will be made before use in the pile. A new carbon stator and aluminum rotor will

* This work is being done with the cooperation of Charles Marsh of the instrument department.

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be machined in the shops while the stainless steel rotor is in operation. An increased neutron signal should be obtained by the substitution of aluminum for stainless steel.

PX641 - The Pile Oscillator - (Moak, Strong)

Recent experiments with the slow pile oscillator indicate that the proximity effect described in the last report, as used for measuring cross-sections of small absorbers (10^{-2} Cm^2 or less), will result in no error due to neutron-spectrum distortion, within the accuracy of measurements. Cross-sections of different absorbers were measured at two positions in the pile; one position was close to the detector and the other position at a considerable distance from the detector. The measurements for the two positions agreed within 1.5%, well below the error caused by pile fluctuations. Use of the proximity effect increases the sensitivity of the instrument by a factor of ten. Macroscopic cross-sections of 0.1 mm^2 may now be measured with 20% probable error.

When using the proximity effect it has been found that hydrogenous materials (i.e. lucite, polystyrene, plexiglas, etc.) act as negative absorbers. This effect was measured for polystyrene, resulting in an apparent negative cross-section of 1.9 mm^2 per gram of the material. Light elements placed near the boron detector, due to their slowing down properties, increase rather than decrease the number of slow neutrons falling on the chamber. Measurements on absorbers containing hydrogen or other light elements

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must therefore be corrected for this effect. One may make these corrections provided the amount of light elements in the sample is known.

A sample of Cb_2O_5 has been measured and the absorption cross-section of Cb has been found to be 1.45 ± 5% barns. The sample was compared with Al as a standard assuming a cross-section of 0.24 barns. The slowing-down corrections for Al and for the oxygen in the Cb_2O_5 sample very nearly balanced out and were neglected.

Some discussion has been started regarding the so-called pile-noise or fluctuations in detector current when no absorber is being moved. The noise has heretofore been attributed to fluctuations in cooling-air poison. Some question has arisen as to whether these fluctuations could be the statistical fluctuations in the neutron flux. Two chambers were set up four feet apart in the pile in the same stringer channel. Current fluctuations in the two chambers were studied simultaneously on an oscilloscope and no correlation was found between them. It is planned to obtain further information about these fluctuations by the use of a harmonic analyzer.

PX10-8 - Crystal Spectrometer - (K. C. Peterson, R. B. Sawyer)

The work with a double crystal spectrometer, reported briefly last month, has been continued. Most of the time has been spent on preliminary investigations of various crystals (NaCl, KCl, LiF, all used as second crystals) so as to determine the proper crystal orientations and counter settings for the various orders of reflection. With the (200)

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planes of NaCl, as many as four orders have been observed. Rocking curves of three of these are shown in Figures 1 - 3. Figure 4 shows a rocking curve for the first order reflection from the (200) planes of LiF and Figure 5 a similar curve for KCl.

Reflection coefficients for these crystals are of the order of 10^{-5} to 10^{-4}, though accurate measurements have not yet been made.

An improved crystal holder has been constructed which permits slow rotation of the crystal about an axis normal to its face, so as to make the proper setting easy. During the last week, the whole apparatus was dismantled and re-assembled so as to cut down stray radiation and reduce the counter background. The first crystal (NaCl) is now completely enclosed in a paraffin-cadmium-lead shield which absorbs the part of the main neutron beam not reflected by the first crystal. The reflected beam emerges from a hole in this shield and strikes the second crystal. This arrangement permits the counter to be moved considerably closer to the second crystal, with a correspondingly greater probability that the reflected beam passes through the whole length of the counter. As soon as this is certain, quantitative measurements will be started.

PX10-18 - Hard Gamma Rays from 25 - (Rose, Burgy)

Final report to be issued soon.

PX10-3 - Long Range Alphas from Plutonium - (Burgy, Bloss, Rose)

The problem of whether long range alphas are emitted from plutonium spontaneously is being investigated with a new sample. The

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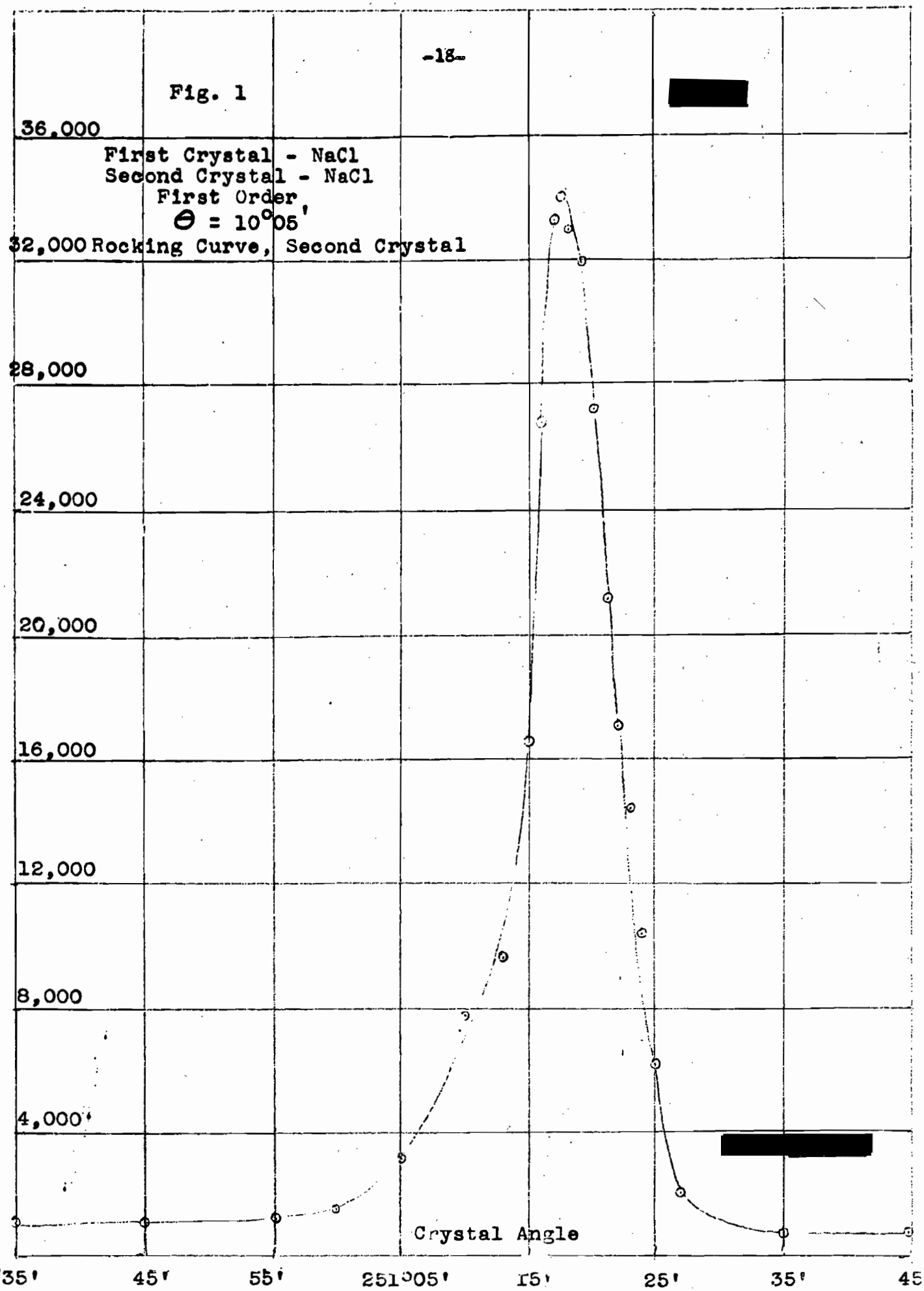

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Fig. 2

First Crystal: NaCl
Second Crystal: NaCl
Second Order

Rocking Curve, Second Crystal

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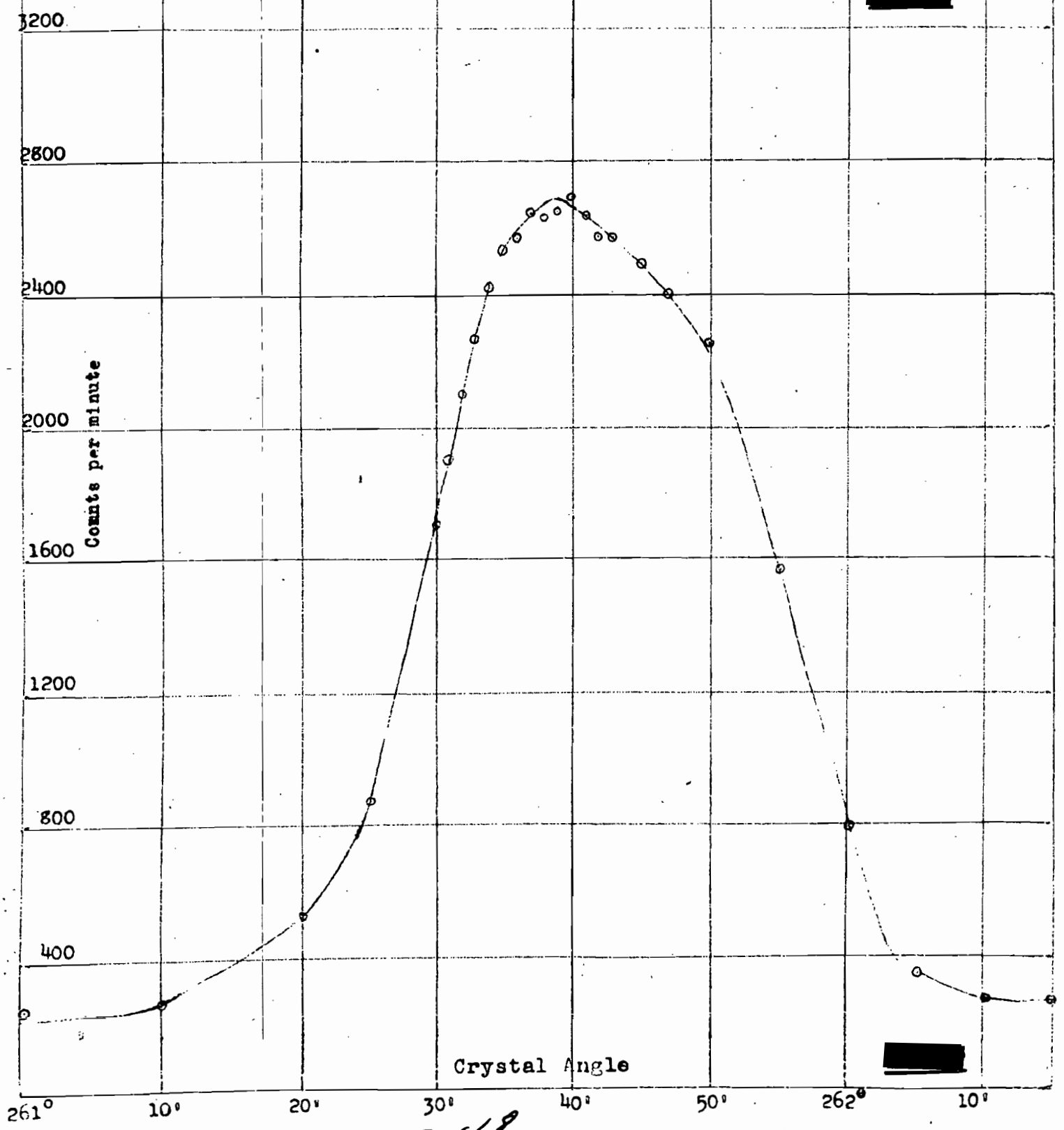

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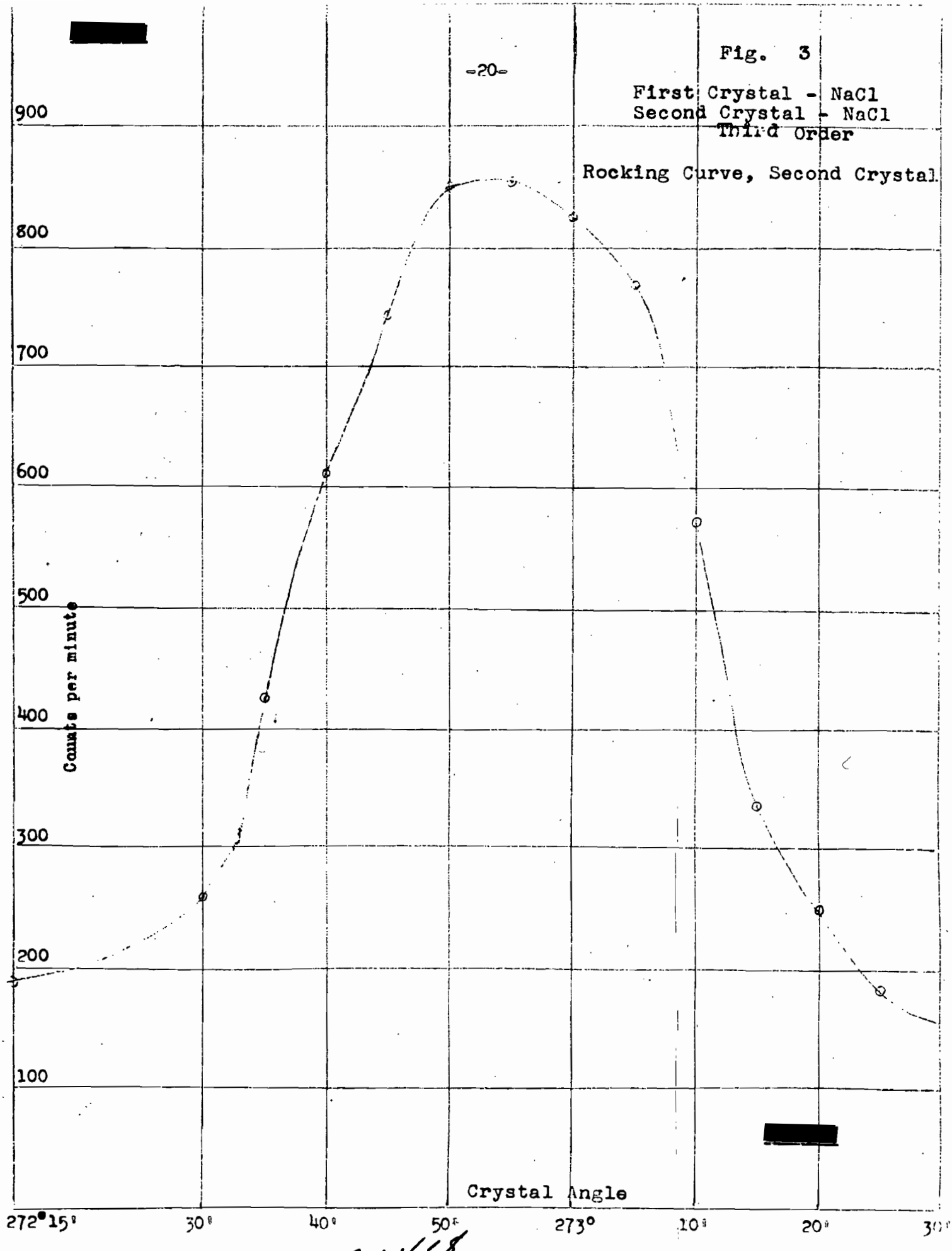
Fig. 3

First Crystal - NaCl
Second Crystal - NaCl
Third Order

Rocking Curve, Second Crystal



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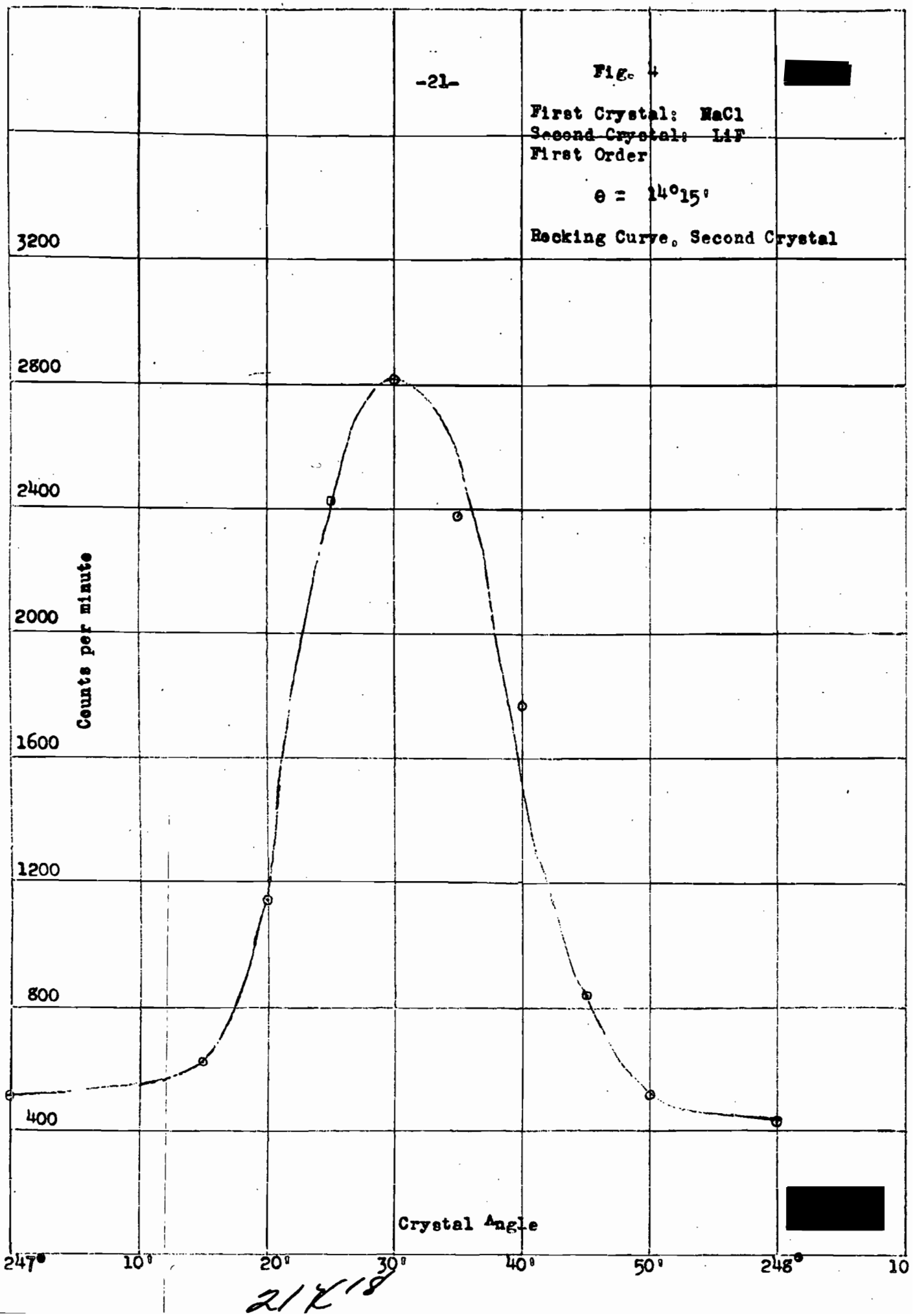

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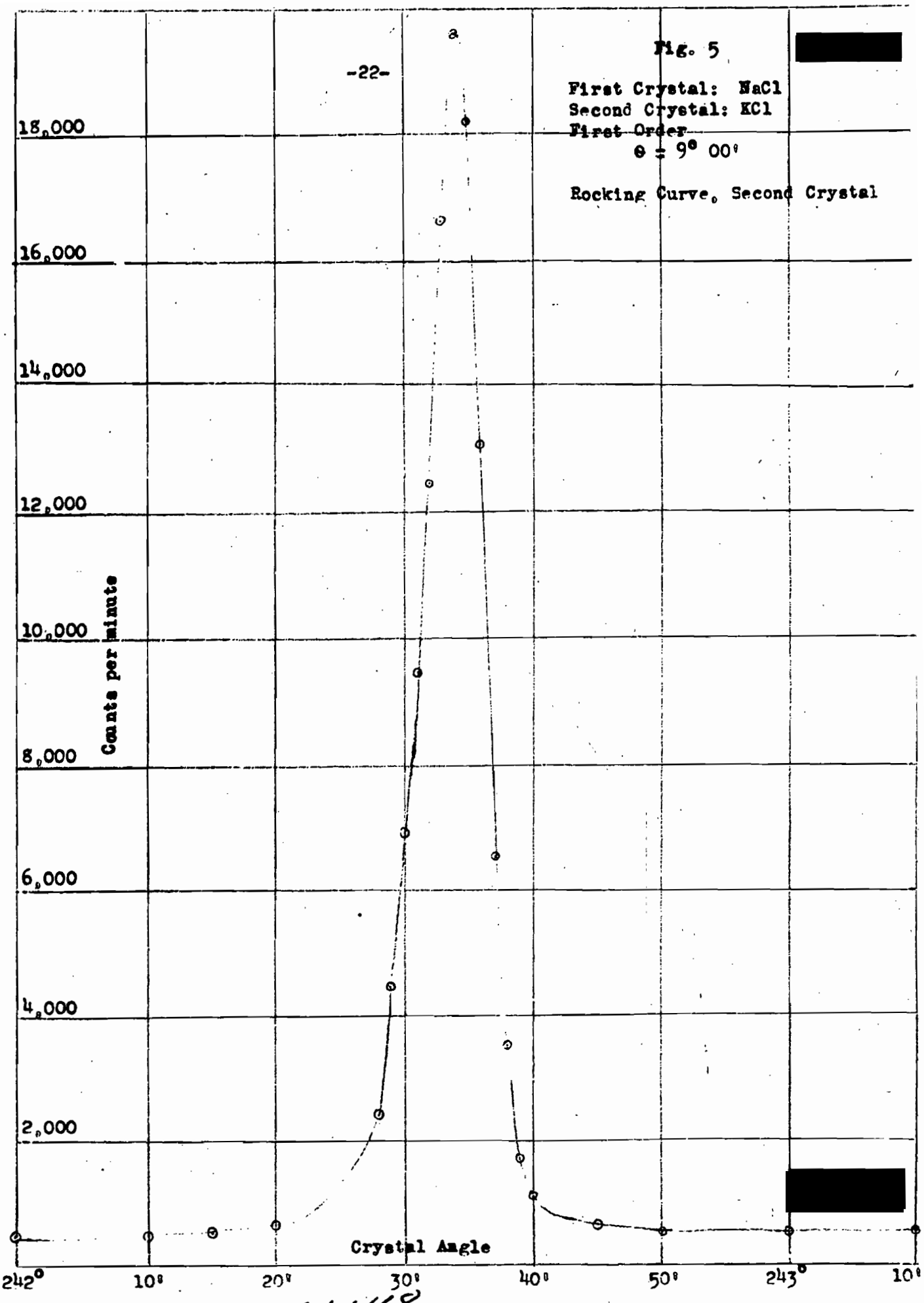

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possibility of confusion due to protons from an α- p reaction has been reduced by using plutonium as the oxalate. Preliminary work has been done with a thick α particle photographic emulsion. With 10.4 mg of Pu, over an area of 23.3 cm^2 on platinum, and covered with gold foil, 22.2 mg/cm^2 thick, 7.2 particles per second were observed. The ranges, measured roughly, were about 10 cm, air equivalent.

A cloud chamber has been readied for further work on this problem. With it, we expect to find whether the particles are alphas or protons (from impurities). Should we verify that they are alphas, we intend to measure their range or range distribution.

PX10-16 - Fission Product and Neutron Induced Activities - (P. W. Levy)

No new results can be reported this month although a good deal of routine work has been done. Sources of Palladium, Silver and Cadmium have been prepared and various instruments have been improved. During a repeat run on 27 day Pa, vacuum trouble was encountered that necessitated an overhaul of the vacuum system.

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Physics Section IV

L. B. Borst, Section Chief
S. Bernstein, Associate Section Chief

Total technical personnel (including supervision)....9 (this period)

Problem Assignment Number	Subject	Status	Percentage of Section Manpower Report Per.	Next Per.
PX10-7	Fissionability of 40-10	Inactive	0	0
PX10-8	Neutron Diffraction	Active	20	20
PX10-10	Deuterium Gamma Ray Spectrometer	Active	10	10
PX10-14	Poisoning Coefficients	Inactive	0	0
PX10-15	Photoneutrons from Fission Products	Active	40	40
PX10-17	Fissionability Studies	Active	20	20
PX4-5	Heat Evolution from Pa^{233}	Active	10	10
		Total	100	100

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PX10-17 - Fissionability Studies - (Floyd, Schofield)

Measurements indicated in the December report upon Np^{239} have been analyzed. The results of these measurements indicate a fission cross-section for thermal neutrons less than 10 barns. The growth curve was started one hour and thirty four minutes after the final chemical separation. This was a preliminary measurement not expected to give definitive results, so that it was not surprising that extrapolation to zero time was uncertain. A second sample, more carefully purified, was prepared by Mr. Halperin of the Chemistry Division, C-1. Unexpected difficulties arose due to background in the photographic material used. No results were obtained from this experiment. When the photographic difficulties have been overcome the work will be repeated.

Cooperative research with Eastman-Kodak has been continued on the development of more satisfactory photographic materials. After extended discussions it was decided to produce in moderate quantities a modified Kodalith emulsion showing most of the desired photographic properties. Fission tracks in this emulsion do not show as a single row of grains but rather as a continuous row of very small blobs. Additional work will be done in determining optimum developing techniques for this material. Samples are expected in the very near future.

The Nier mass spectrometer is now being coupled to the sample handling equipment and is very nearly ready for the first out-gassing operation.

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PX4-5 - Heat Evolution from Pa^{233} -

Work on this problem has been interrupted to complete a long-standing report on pile characteristics required for the PPR. The differential calorimeter required for this experiment should be completed during the next month. Its assembly is under way at the present time. The thorium billets required for the experiment have arrived.

Shielding of Enriched Pile

Attention has been given to the problem of shielding the new enriched unit. This work will require additional effort as pile design progresses. The general recommendation for shielding was to use a concrete pour for the principle portions of the structure but to leave panels to be filled with blocks of iron masonite W shield. Calculations have been made on the required thickness and properties of the shield. 4' of W shield consisting of five 6" layers of iron separated by four 4½" layers of hydrogenous material, e.g. masonite. These panels will permit apparatus to be brought to a minimum distance from the neutron source. Inadequate tests are available on the properties of the Clinton shield to determine the rees recommended mix and thickness of the concrete equipment. For preliminary design purposes an 8' slab of some sort of special concrete containing $BaSO_4$ or equivalent atomic weight material has been recommended. The difficulty of getting hydrogen into a stable dry structure is no less acute in 1946 than when the Clinton shield was designed. Various possibilities are still being investigated.

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PX10-15 - Photoneutrons from Fission Products - (Wolfe, Steinberg, Bernstein)

All equipment has finally been assembled for the measurement of the photoneutrons produced by gamma rays from the short-lived fission products. Considerable time was lost awaiting delivery of enriched oxide deposits required for the fission chambers. These samples have now arrived. The chambers have been assembled. All circuits are in working order and the apparatus is ready to deliver data.

PX10-8 - Neutron Diffraction - (Hasbrouck, Borst)

A billet of magnesium metal 2" in diameter and 24" long has been grown. Preliminary measurements indicate that a large fraction of this billet constitutes a single crystal lattice. The reflecting qualities of planes with spacings down to one Å appear to be satisfactory for high energetic work.

Remote control equipment associated with the preparation of a Xe^{135} sample adequate for spectral measurements is nearing completion.

PX10-10 - Deuterium Gamma Ray Spectrometer - (Dial)

Various bugs in this equipment have been in the process of investigation. No prediction can be made at the present time of the serviceability under operating conditions.

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