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Description of Sand-Water Pumping Experiment and Preliminary Photographic Investigation

Allen F. Westerdahl

Mining 68
Spring Semester, 1957
Mine Practice

Report
Submitted to
Professor K. S. Stout

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and
PRELIMINARY PHOTOGRAPHIC INVESTIGATION

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Mr. Koehler S. Stout
Assistant Professor of Mining
Montana School of Mines
Butte, Montana

Dear Mr. Stout:

In accordance with your instructions at the beginning of this semester, I submit the following report on Description of Sand-Water Pumping Experiment and Preliminary Photographic Investigation as partial fulfillment of the requirements for Mining 68.

A general description of the pumping experiment, as it is set up and operated at the Montana School of Mines, is presented in the first section of the report. This description may serve as a familiarization for anyone desiring to continue work with the experiment.

The preliminary photographic investigation was carried out to determine the feasibility of photography of flow conditions in clear plastic pipes. Results of this investigation indicate that it may be possible to photograph flow conditions successfully, if sufficient fluorescent material is flowing through the pipes.

Thanks are due The Anaconda Company, Ventilation Department and The Montana Bureau of Mines and Geology for the use of their ultraviolet lamps; David S. Johnson, student at the Montana School of Mines for the use of his photographic equipment and his help in the photography; and Wilson Hong for the film development.

Very truly yours,

Allen F. Westerdahl

Allen F. Westerdahl

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

The objective of this report is threefold: to provide a brief description of the Sand-Water Pumping Experiment; to describe the flow of sand and water in the experimental equipment; and to present the results of a preliminary photographic investigation of fleurescent minerals in clear plastic pipes.

Two engineering drawings will serve to illustrate the discussion of the first two objectives in the first part of the report, and photographs will show the results of the third objective in the second part.

DESCRIPTION OF SAND-WATER PUMPING EXPERIMENT

The general description of the slurry pumping experiment includes: 1. the Main Pumping System, 2. the Flow-Determining System, and 3. the Operating Procedure. To make the description concise and to illustrate the flow of material more effectively, many mechanical and construction details are omitted in this description.

Main Pumping System

The explanation of the Main Pumping System, with number reference to equipment in Figure 1, is as follows:

1. The sand, stored in two, 10-yd. storage bins, feeds by gravity onto a 12-in. horizontal belt conveyor. Sand discharged from the conveyor is elevated by a $3\frac{1}{2}$ by 5 in. bucket and chain elevator a distance of $28\frac{1}{2}$ ft., where it is passed through a 10 by $35\frac{1}{2}$ in. vibrating screen (cloth opening of $\frac{1}{4}$-in.). The undersize discharge from the screen is the final product entering the feed bin (1).

2. An adjustable vertical gate (Figure 2, No. 5) controls the sand discharge from the feed bin onto an 18-in. conveyor feed belt (4). A 2-hp gear

motor (3) is used to operate the belt through a chain drive.

3. To assure efficient flow of sand to the belt, the bin is equipped with a Syntron vibrator (2) which is controlled by a rheostatic vibrator control (13). The proper flow of sand to the belt is necessary to the effective control of pulp density.
4. Sand from the belt feed discharges into the mixing cone (10) where it mixes with metered (6) water entering at the top of the cone. The water, controlled by individual valves (7), discharges from hoses spaced equally around the perimeter of the cone. Water pressure can be read at pressure point 10.
5. The bottom of the cone is connected to a section of 4-in. steel pipe equipped with a compressed air manifold (11) which admits air to assure adequate suspension of the sand-water mixture.
6. Between the air manifold and the pump is a section of 4-in. clear plastic pipe (12) used for observation of the pump intake and for photography of flow conditions.
7. A Robbins and Myers, 2 stage Moyno sand pump (450 to 1750 rpm)(15) is used to pump the 4-in. slurry intake. The pump has a helical screw rotor that imparts a forward velocity to the sand slurry. "This type pump was chosen to secure the intrinsic advantage of positive displacement with a minimum of abrasive comminution action between individual particles of the slurry." (1:2)
8. A 7.5 Westinghouse induction motor (1165 rpm)(15B) with adjustable base operates the pump with a v-belt drive. Power measurements supplied by a Westinghouse wattmeter (14) connected onto the motor circuit and speed measurements are taken with a tachometer attached to the driven shaft.
9. The Speed Selector variable pitch sheaves (15A) provides variable speed

for the pump at a maximum power transmission of $7\frac{1}{2}$ hp. The pump sheaves, which have a maximum allowable speed range of from 575 to 2300 rpm, can be adjusted by hand while the pump is in operation.

10. Sand-slurry discharge from the pump flows past the stand pipe (16) and into a section of 2-in. clear plastic observation pipe (17). The stand pipe serves as a release for air in the slurry and as a pressure flush line for the upper system of test pipe. Connected to the stand pipe is a piezometer air purge (19).

11. A reagent feed manifold system (18) may replace the section of 2-in. clear plastic pipe thus providing a method for introducing flocculation agents into the slurry flow. The feed manifold is equipped with a check valve (18A) and a flush water line (18B). Six reagent injection points, spaced evenly and offset from one another by 60 degrees, provide adequate mixing of reagent with the slurry.

12. The slurry passing through the 2-in. plastic pipe or reagent manifold may be pumped either out of the system and into the discharge launder (20) or recirculated back through the upper pipe system.

13. A flow-measurement control valve (5) is used to transfer the slurry flow into the flow-determining system shown in Figure 2. A quick-acting valve, near the top of the mixing cone, stops the slurry recirculation of the main pumping system when the flow-determining system is to be used.

14. Pressure points are located at nine points along the main pumping system and are numbered on the overlay of Figure 1. Heavy sleeves, drilled and tapped for nipples to which gate valves are attached, are used as the pressure points. Connected to the gate valves are diaphram pressure guages or other pressure measurement apparatus.

Flow-Determining System

The system of flow measurement, with reference to numbers in Figure 2, may be described as follows:

1. The sand-water slurry leaves the main pumping system through the quick-acting control valve (6) and enters a 2-in. rubber intake line (22). A quick-acting valve near the mixing cone in the main system must be closed to prevent the slurry from recirculating through the main system during flow measurement.
2. Slurry from the intake line discharges into a 55-gal flow-measuring drum (16) mounted on a platform scale (17). Pulp filling the drum can thus be weighed and the weight can be used to determine the quantity of flow passing through the system. A ring of ½-in. pipe in the bottom of the drum contains air jets to assist in the admixture of the slurry.
3. A valve on the bottom of the drum controls the slurry flow into the air-operated sludge pump (15). A compressed air outlet (19) supplies air to the sludge pump and the air jets in the drum.
4. Discharge from the sludge pump may either be returned to the main pumping system through 2-in. return line (21) or discharged into the sewer through the flush line (20).

Operating Procedure

To provide a basis for experimental operation of the sand-water pumping experiment, it is desirable to outline the normal operating procedure. Although in operating practice, the exact procedure will be fixed by experimental conditions, a general operational procedure may be presented as follows:

1. Fresh water is introduced into the cone until the cone is almost filled, at which time the slurry pump is started. The discharge valve (Figure 1, far right) is closed so that water will flush the entire pipe system.

After the water is recirculating the discharge valve is opened and the recirculating valve (above the discharge valve) is closed allowing the water to flow into the discharge launder.

2. The pump speed should be high enough to provide a line velocity in excess of the critical before the introduction of solids into the line. Solids are introduced by starting the conveyor belt motor and Syntron vibrator simultaneously. Water flow is controlled by the water meter for the desired pulp density.
3. If the pulp is being recirculated rather than discharged from the system, the sand feed and water feed are stopped when the desired pulp density is reached.
4. Prior to taking pressure measurements a controlled quantity of air is introduced at the compressed air manifold to assist in the admixture of the slurry.
5. The pump speed is adjusted prior to taking power and pressure measurements.

PRELIMINARY PHOTOGRAPHIC INVESTIGATION

The purpose of this section of the report is to provide basic information concerning the photography of fluorescent minerals in clear plastic pipe. The ultimate objective of such an investigation is to develop a photographic method to illustrate flow conditions in transparent pipe of the Sand-Water Pumping Experiment.

This preliminary investigation is devoted primarily to the selection of equipment and the results of preliminary tests. Test results, illustrated by Figures 3 to 8, cover 1. film latitude and A.S.A. rating, 2. light reflection, and 3. coverage. The photographic data for the tests conducted is compiled in the appendix of this report. The photographic setup and procedure will not be discussed as they are based on standard practice and depend on the position and condition of the pipe.

Equipment Selection

Camera and Lens

A Pentacon 35 mm prismatic, single-lens reflex camera with a focal plane shutter and ground glass focusing was used in all the photographic tests. This camera is provided with a Carl Zeiss Tessar 50 mm, f 2.8 coated lens used with an Accura 15 mm extension tube.

The selection of camera and lens was based upon two considerations:

1. The need to focus on ground glass. This was necessary to work at short distances, where depth of field was shallow and the ultra-violet wavelength would make normal lens markings unusable. (It may be noted that ultra-violet light, in passing through a visible light calibrated lens system, will focus in front of the film plane. This gives an image which is out of focus unless corrected by ground glass focusing.)
2. The need of focusing the lens system at distances shorter than provided by normal focusing mounts. This was solved by using an extension tube of 15 mm between the camera and lens.

Films

Dupont S-X Pan: A panchromatic safety film rated by the manufacturer at A.S.A. 300 daylight and 260 tungsten was chosen to provide a high-speed, fine-grain panchromatic film that could be exposed at A.S.A. ratings up to 4000 if necessary. S-X Pan was developed in FR X-500 developer with a 1:10 dilution.

Eastman Kodak Tri-X: A panchromatic safety film rated by the manufacturer at A.S.A. 200 daylight and 160 tungsten was used in Test 1, Roll 3 as a high-speed medium grain film that could be used should the S-X Pan prove unsatisfactory.

Filters

The Tiffen Series VI Yellow 2, Orange 1, and Green 1 filters were chosen for the tests because they all absorbed ultra-violet light and passed visible light near the upper end of the spectrum.

Light Sources

Glo-Craft Model 108: This ultra-violet lamp with a wavelength of approximately 2600 Å provided maximum illumination for only about 9 inches of pipe. Scheelite fluoresces well under this lamp and could be used as the mineral to be photographed.

General Electric Glow-Blb Blacklight: Two-40 watt, 48-in. lamps with a wavelength of approximately 3400 Å provided illumination for up to 5 ft of pipe. The advantage of these lamps is the long coverage with evenly distributed illumination. Although scheelite does not fluoresce under these lamps, autunite, the mineral used in the tests, fluoresces rather brightly.

Pipe

A 2-in. diameter clear plastic pipe, approximately 15-inches long was used in all the tests conducted for this investigation.

Results and Conclusions

The results of the series of tests conducted may be observed in Figures 3 through 8 in the appendix. From these tests it may be concluded that the photography of flow conditions is feasible providing there is sufficient fluorescent material in the sand-water slurry passing through the pipe.

In Figure 3, the $\frac{1}{2}$ sec exposure is correct, but the fluorescence of the mineral is obscured by reflected ultra-violet light. In Figure 4, a Tiffen Yellow 2 filter was used to absorb the ultra-violet light reflected from the plastic pipe. The effective exposure time is equal with the use of a filter factor of 2.

The previous discussion also holds for Figures 5 and 6. When these photographs are compared with Figures 3 and 4, the latitude of the film becomes evident.

The filtration of the ultra-violet reflected light with a yellow filter is again confirmed with the tests in Figures 7 and 8, in these cases using a different light source. Figure 7, exposed at ½ sec, compared with Figure 8, exposed 1/5 sec with a yellow filter, again illustrates the desirable film latitude.

Film

Latitude: Dupont's S-X Pan, upon which most of the tests were photographed, shows an exposure latitude of one shutter stop underexposed and one shutter stop overexposed from the ideal exposure. This latitude makes S-X Pan valuable in cutting the amount of experimentation to determine the proper exposure index. The latitude also gives a negative of equal density where light intensity may vary from center to edges of the frame.

A.S.A. Rating: During the course of the tests, varying lengths and temperature of film development were used. There appears to be little difference in the film's exposure rating by using the following development procedure for the S-X Pan:

1. 10 minutes at 70°F
2. 10 minutes at 75°F
3. 12 minutes at 75°F

There is however an increase of approximately two shutter speeds by using 15 minutes at 70°F, with no apparent increase in film grain. This would indicate that the film could be exposed successfully at much higher ratings. S-X Pan has been exposed successfully at ratings of A.S.A. 4000 commercially. (2:78)

Reflection

It became apparent after the first test that reflection from the plastic pipe was going to obscure the fluorescence of the mineral autunite. The reflection was of ultra-violet light and was of a wavelength in the response range of the film.

To eliminate the reflection it was necessary to absorb the light of the undesirable wavelength and still admit the visible light of the autunite fluorescence. To accomplish this absorption, yellow, orange, and green filters were used on the camera. The yellow and green filters successfully absorbed the ultra-violet light and eliminated the reflection that was previously visible on the photographs.

For further tests, the yellow filter was chosen because it admits more visible light than the green filter and thus requires less exposure correction.

From the comparison of Test I with Test II, it appears that to minimize the width of the reflection, the light-pipe-camera angle should be kept to a minimum and not to exceed 30 degrees. This angular relationship held only for the spot-light type Glo-Craft lamp and apparently the reflection from the General Electric Glow-Blb had no relation to the angle.

<u>Coverage</u>

Camera coverage in the first three tests was 9 inches of pipe. It was necessary to use a 15 mm extension tube to get to within 7 inches of the pipe for this coverage. In the fourth or last test, coverage was extended to one foot and no extension tube used on the camera. By using different enlargement ratios in printing, the image could be printed to equal size.

To photograph a longer section of pipe, the pipe-camera distance could be increased, but a correction in exposure would be necessary. It must be remembered that as the coverage increases, the enlargement ratio must be increased to maintain the same image size. This increase in enlargement also will cause resolution to decrease and the grain size to increase.

APPENDIX

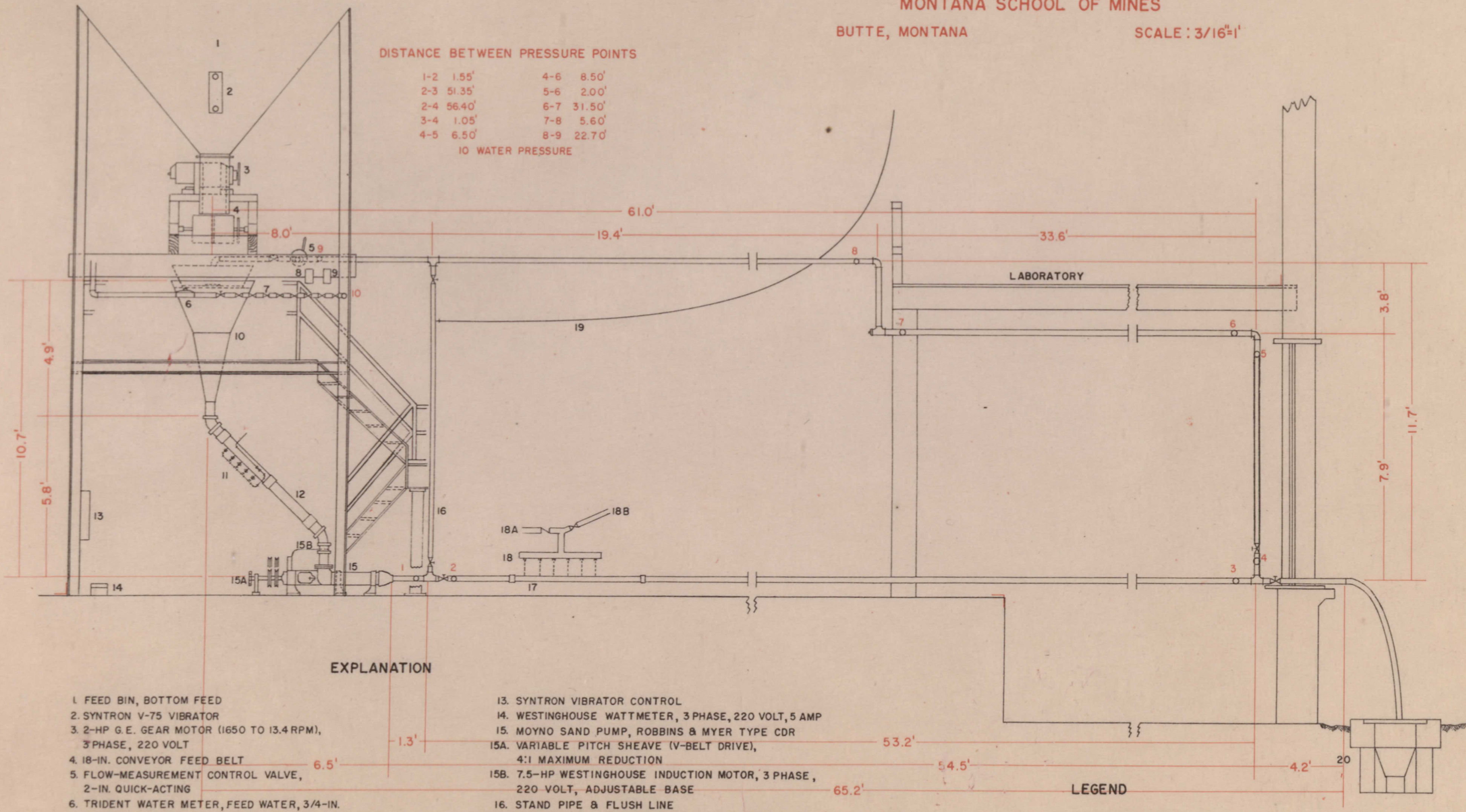
Figure 1

SAND-WATER PUMPING EXPERIMENT

SIDE VIEW

MONTANA SCHOOL OF MINES

BUTTE, MONTANA SCALE: 3/16"=1'



DISTANCE BETWEEN PRESSURE POINTS

1-2	1.55'	4-6	8.50'
2-3	51.35'	5-6	2.00'
2-4	56.40'	6-7	31.50'
3-4	1.05'	7-8	5.60'
4-5	6.50'	8-9	22.70'

10 WATER PRESSURE

EXPLANATION

1. FEED BIN, BOTTOM FEED
2. SYNTRON V-75 VIBRATOR
3. 2-HP G.E. GEAR MOTOR (1650 TO 13.4 RPM), 3 PHASE, 220 VOLT
4. 18-IN. CONVEYOR FEED BELT
5. FLOW-MEASUREMENT CONTROL VALVE, 2-IN. QUICK-ACTING
6. TRIDENT WATER METER, FEED WATER, 3/4-IN.
7. CONTROL VALVES, FEED WATER, 3/4-IN.
8. SWITCH, GEAR MOTOR
9. SWITCH, PUMP MOTOR
10. MIXING CONE
11. COMPRESSED AIR MANIFOLD
12. 4-IN. CLEAR PLASTIC OBSERVATION PIPE
13. SYNTRON VIBRATOR CONTROL
14. WESTINGHOUSE WATTMETER, 3 PHASE, 220 VOLT, 5 AMP
15. MOYNO SAND PUMP, ROBBINS & MYER TYPE CDR

15A. VARIABLE PITCH SHEAVE (V-BELT DRIVE), 4:1 MAXIMUM REDUCTION

15B. 7.5-HP WESTINGHOUSE INDUCTION MOTOR, 3 PHASE, 220 VOLT, ADJUSTABLE BASE

16. STAND PIPE & FLUSH LINE
17. 2-IN. CLEAR PLASTIC PIPE OR STEEL PIPE
18. REAGENT FEED MANIFOLD

18A. REAGENT INTAKE

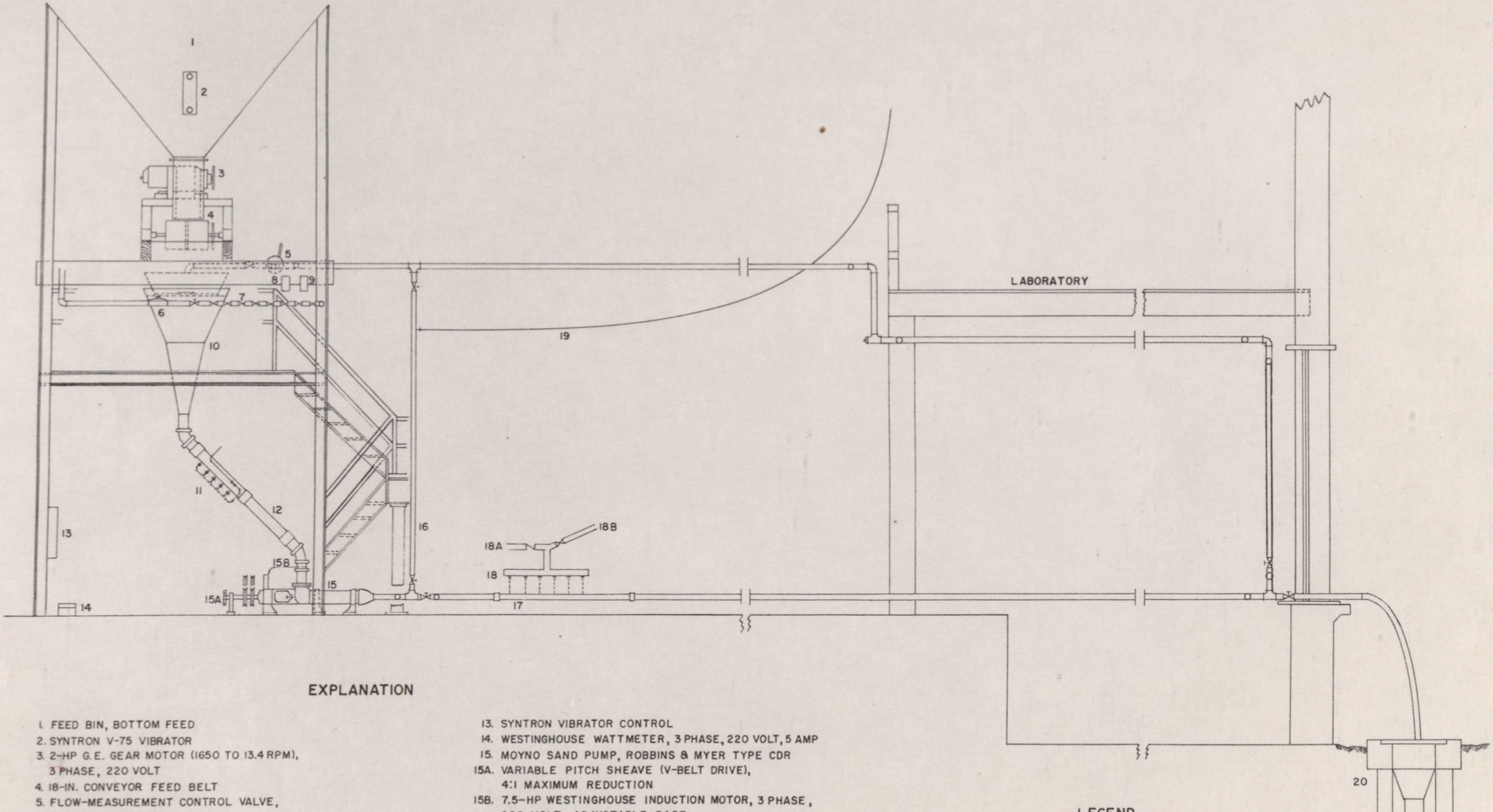
18B. FLUSH WATER

19. AIR PURGE (PIEZOMETER)
20. DISCHARGE LAUNDER

LEGEND

- ○ PRESSURE POINT
- GATE VALVE
- GLOBE VALVE
- CHECK VALVE
- QUICK-ACTING VALVE

Figure 1



EXPLANATION

1. FEED BIN, BOTTOM FEED
2. SYNTRON V-75 VIBRATOR
3. 2-HP G.E. GEAR MOTOR (1650 TO 13.4 RPM), 3 PHASE, 220 VOLT
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11. COMPRESSED AIR MANIFOLD
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15A. VARIABLE PITCH SHEAVE (V-BELT DRIVE), 4:1 MAXIMUM REDUCTION
15B. 7.5-HP WESTINGHOUSE INDUCTION MOTOR, 3 PHASE, 220 VOLT, ADJUSTABLE BASE
16. STAND PIPE & FLUSH LINE
17. 2-IN. CLEAR PLASTIC PIPE OR STEEL PIPE
18. REAGENT FEED MANIFOLD
18A. REAGENT INTAKE
18B. FLUSH WATER
19. AIR PURGE (PIEZOMETER)
20. DISCHARGE LAUNDER

LEGEND

- ○ PRESSURE POINT
- GATE VALVE
- GLOBE VALVE
- CHECK VALVE
- QUICK-ACTING VALVE

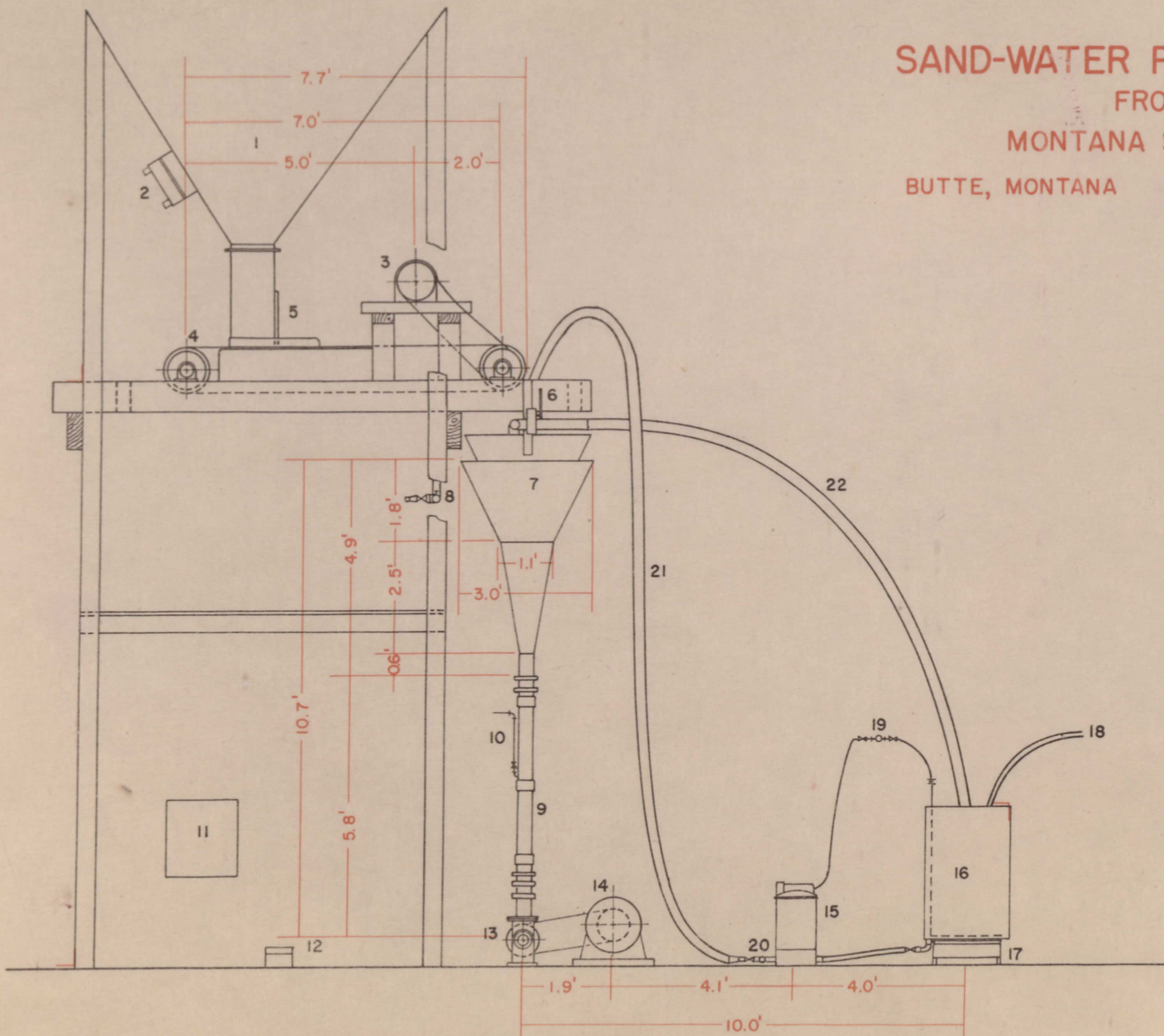
Figure 2

SAND-WATER PUMPING EXPERIMENT

FRONT VIEW

MONTANA SCHOOL OF MINES

BUTTE, MONTANA SCALE: 1/4" = 1'

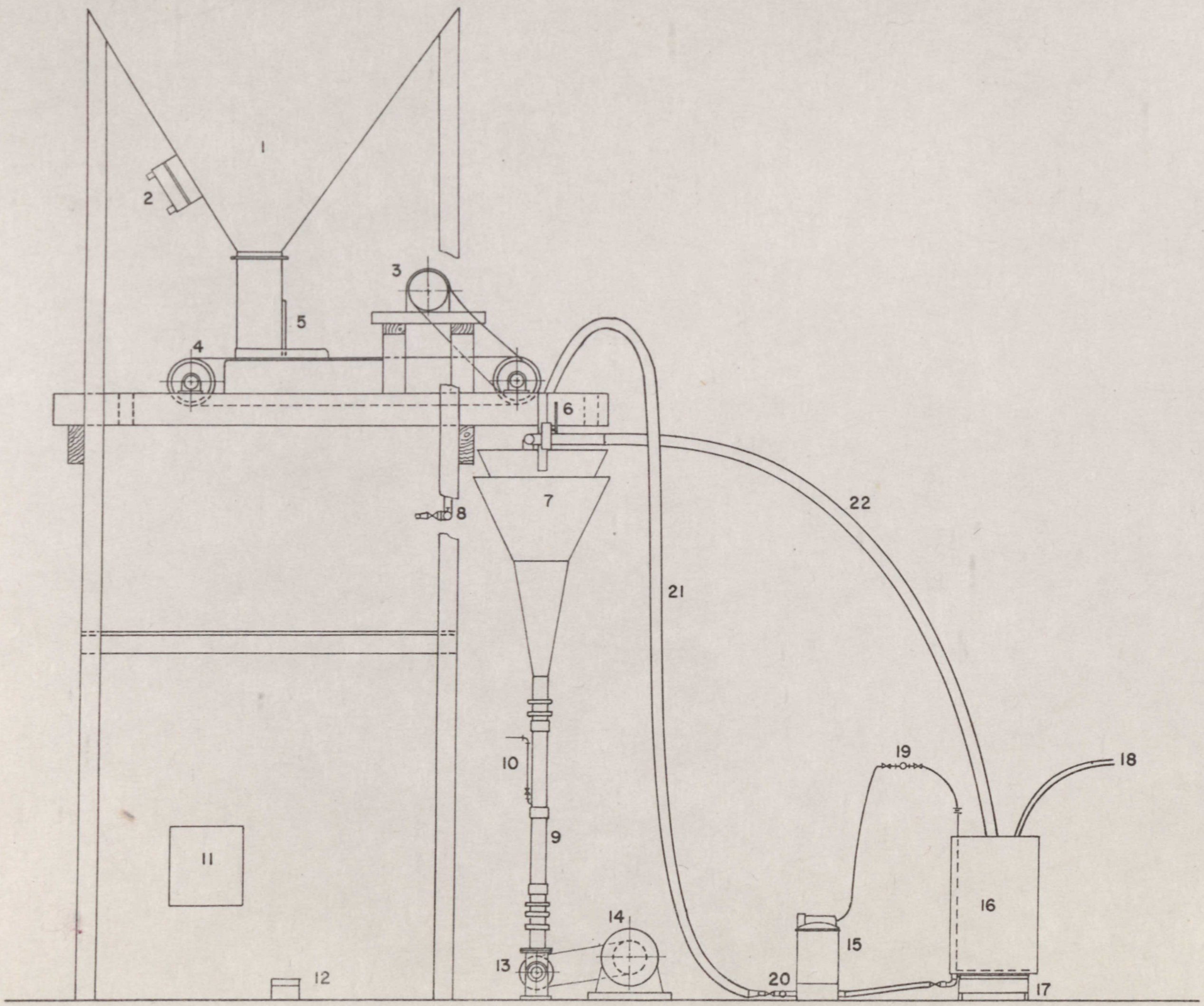


EXPLANATION

1. FEED BIN, BOTTOM FEED
2. SYNTRON V-75 VIBRATOR
3. 2-HP G.E. GEAR MOTOR (1650 TO 13.4 RPM), 3 PHASE, 220 VOLT
4. 18-IN. CONVEYOR FEED BELT
5. VERTICAL SAND FEED GATE
6. FLOW-MEASUREMENT CONTROL VALVE, 2-IN., QUICK-ACTING
7. MIXING CONE
8. FEED WATER
9. 4-IN. CLEAR PLASTIC OBSERVATION PIPE
10. COMPRESSED AIR MANIFOLD
11. SYNTRON VIBRATOR CONTROL
12. WESTINGHOUSE WATTMETER, 3 PHASE, 220 VOLT, 5 AMP
13. MOYNO SAND PUMP, ROBBINS & MYER TYPE CDR
14. 7.5-HP WESTINGHOUSE INDUCTION MOTOR, 3 PHASE, 220 VOLT, ADJUSTABLE BASE
15. SLUDGE PUMP, AIR OPERATED
16. 55-GAL FLOW-MEASURING DRUM
17. PLATFORM SCALE
18. WATER SOURCE
19. COMPRESSED AIR SOURCE
20. FLUSH LINE
21. RETURN LINE
22. INTAKE LINE

⊶ GLOBE VALVES

Figure 2



EXPLANATION

1. FEED BIN, BOTTOM FEED
2. SYNTRON V-75 VIBRATOR
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7. MIXING CONE
8. FEED WATER
9. 4-IN. CLEAR PLASTIC OBSERVATION PIPE
10. COMPRESSED AIR MANIFOLD
11. SYNTRON VIBRATOR CONTROL
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17. PLATFORM SCALE
18. WATER SOURCE
19. COMPRESSED AIR SOURCE
20. FLUSH LINE
21. RETURN LINE
22. INTAKE LINE

⋈ GLOBE VALVES

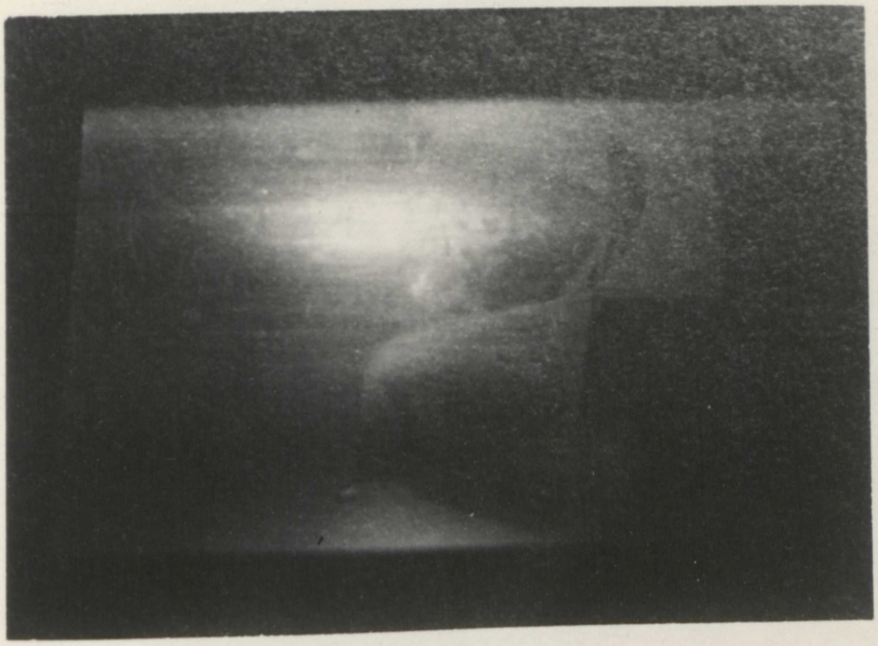

Figure 3

1/2 sec at f 2.8, No Filter
Test I, Roll 1, Frame 4

Figure 4

1 sec at f 2.8, Yellow Filter
Test II, Roll 4, Frame 4

Figure 5

1/5 sec at f 2.8, No Filter
Test I, Roll 1, Frame 5

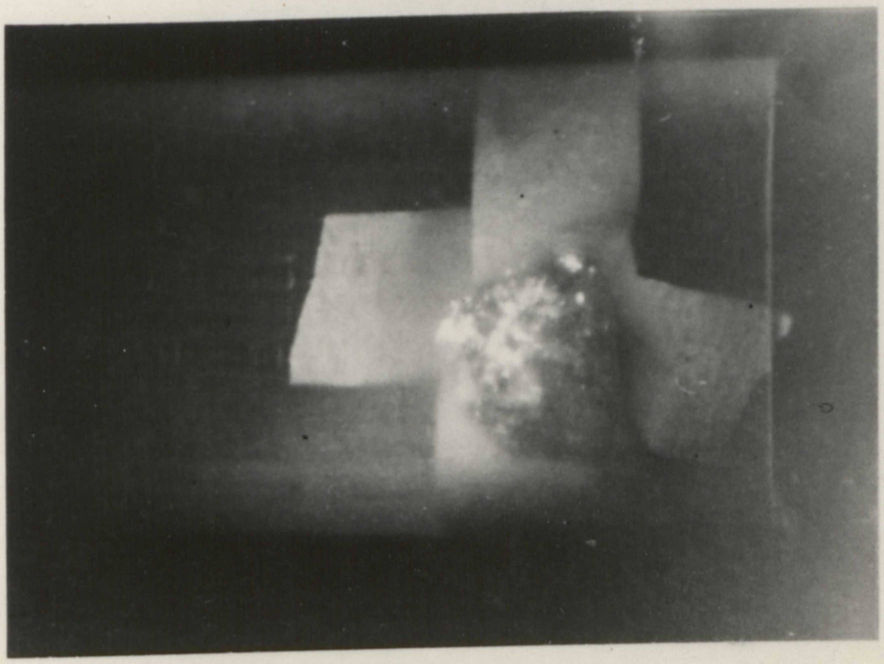

Figure 6

1/2 sec at f 2.8, Yellow Filter
Test II, Roll 4, Frame 5

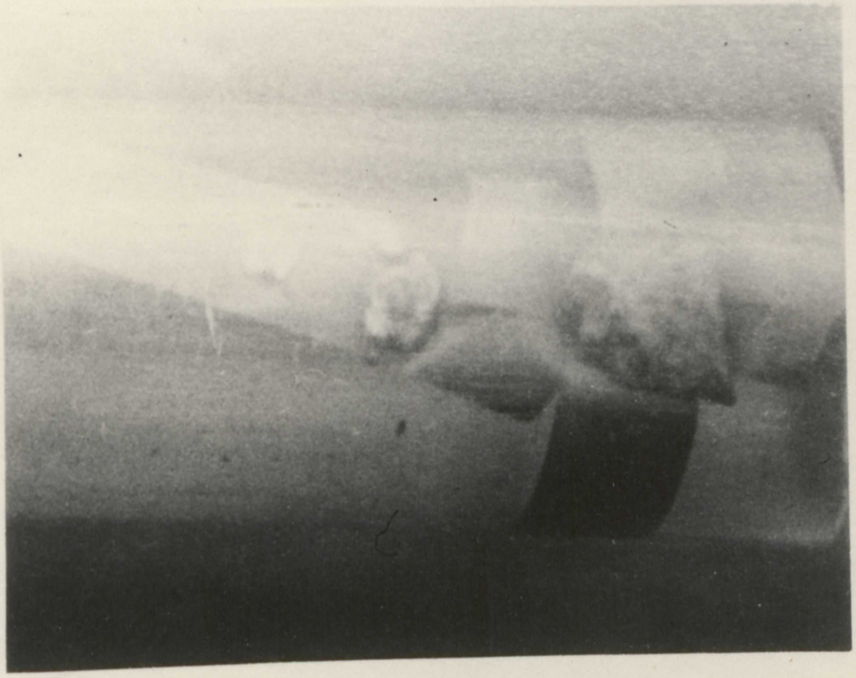

Figure 7

1/2 sec at f 2.8, No Filter
Test IV, Roll 6, Frame 1

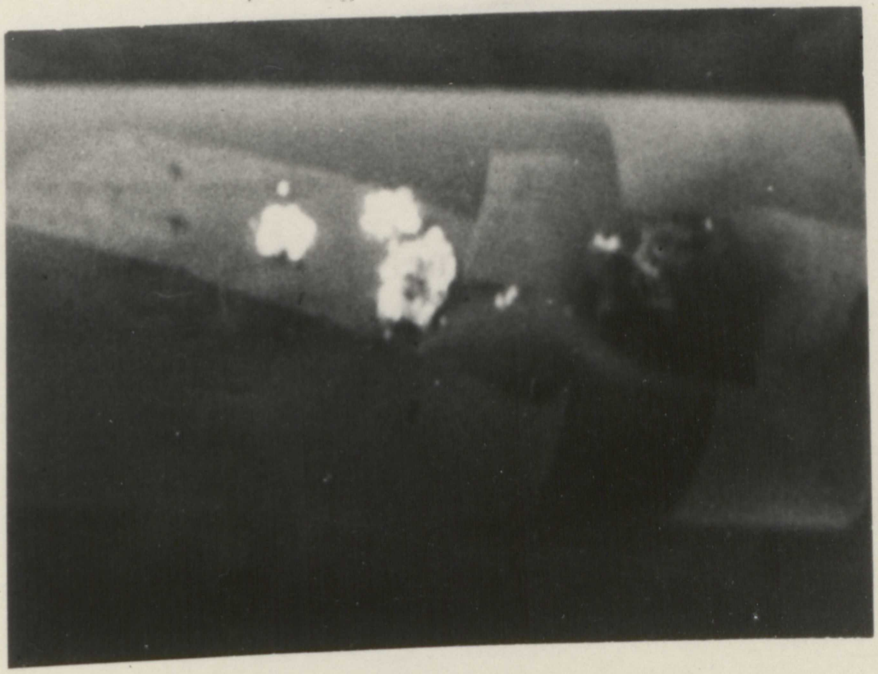

Figure 8

1/5 sec at f 2.8, Yellow Filter
Test IV, Roll 6, Frame 2

PHOTOGRAPHIC DATA

Test I — Roll 1

Camera: Pentacon

Lens: 2.8 C. Z. Tessar

Extension Tube: 15 mm

Light Source: Glo-Craft Model 108
Light distance: 3 inches
Camera distance: 7 inches
Lighting angle: 45°

Film Type: S-X Pan

Development: (A.S.A. 1000)
FR X-500, 1:10 dilution
10 minutes at 70°F

f Stop: 2.8

Frame	Exposure Time (sec)
1	5
2	3
3	1
4	1/2
5	1/5
6	1/10
7	1/20

Test I — Roll 2

Camera data same as Test I, Roll 1.

Lighting data same as Test I, Roll 1.

Exposure data same as Test I, Roll 1.

Film Type: S-X Pan

Development: (A.S.A. 2000)
FR X-500, 1:10 dilution
15 minutes at 70°F

Test I — Roll 3

Camera data same as Test I, Roll 1.

Lighting data same as Test I, Roll 1.

Film Type: Kodak Tri-X

Development: (A.S.A. 800)
FR X-33
14 minutes at 70°F

Frame	Exposure Time (sec)
1	30
2	25
3	20
4	15
5	10
6	8
7	5
8	3
9	1
10	1/2
11	1/5
12	1/10
13	1/20
14	1/50
15	1/100
16	1/200
17	1/500
18	1/1000
19	1 min
20	3 min

Test II — Roll 4

Camera data same as Test I, Roll 1.

Light Source: Glo-Craft Model 108
Light Distance: 14 inches
Camera Distance: 7 inches
Lighting Angle: 30°

Film Type: S-X Pan

Development: Same as Test I, Roll 1.

Frame	Filter Type Color	Filter Factor	Exposure Time (sec)
1	none used		1
2	none used		1/2
3	none used		1/5
4	Tiffen Yellow	2	1
5	Tiffen Yellow	2	1/2
6	Tiffen Orange	3	2
7	Tiffen Orange	3	1
8	Tiffen Green	4	3
9	Tiffen Green	4	2

Test III — Roll 5

Camera data same as Test I, Roll 1.

Light Source: G. E. Glow-Blb
Light Distance: 7 inches
Camera Distance: 7 inches
Lighting Angle: 60°

Film Type: S-X Pan

Development: Same as Test I, Roll 1.

Frame	Exposure Time (sec)
1	1/10
2	5
3	3
4	1
5	1/2
6	1/5
7	1/10
8	1/20
9	1/50
10	1/100

Test IV — Roll 6

Camera data same as Test I, Roll 1, except no extension tube used.

Film Type: S-X Pan

Development: (A.S.A. 1200)
FR X-500, 1:10 dilution.
10 minutes at 75°F.

Light Source: Exposures 1-8
G. E. Glow-Blb
Light Distance: 8 inches
Camera Distance: 17 inches
Lighting Angle: 75°

Light Source: Exposures 9-10
Glo-Craft Model 108
Light Distance: 14 inches
Camera Distance: 17 inches
Lighting Angle: 20°

Frame	Filter Type	Filter Color	Filter Factor	Exposure Time (sec)
1	none used			1/2
2	Tiffen	Yellow	2	1/5
3	none used			1/10
4	Tiffen	Yellow	2	1/20
5	none used			1/50
6	Tiffen	Yellow	2	1/100
7	none used			1/200
8	Tiffen	Yellow	2	1/500
9	none used			1/200
10	Tiffen	Yellow	2	1/500

Test IV   Roll 7

Camera data same as Test IV, Roll 6.

Lighting data same as Test IV, Roll 6.

Exposure data same as Test IV, Roll 6.

Film Type: S-X Pan

Development: (A.S.A. 1600)
FR X-500, 1:10 dilution
12 minutes at 75°F.

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