SUNFLOWE[illegible]

AMMUNIT[illegible]

HERCULES [illegible]

LAWRENCE [illegible]

SUN 143-33

Solventless (Extruded) Powder (N-5) - Mechanized Roll

Design Engineering for the Next Generation
Mechanized Roll Facility

Final Report

Project 4810.16.3698.2

J. A. Montgomery
Shep Lampkin

15 April 1970

SUN 143-33

Solventless (Extruded) Powder (N-5) - Mechanized Roll

Design Engineering for the Next Generation Mechanized Roll Facility

Final Report

Project 4810.16.3698.2

Date 15 April 1970 Author J. A. Montgomery
Shep Lampkin

Date April 15, 1970 Approved [illegible]
4/16/70 [illegible]

183

TABLE OF CONTENTS

Page

Appendix

INTRODUCTION

This project had as its objective the development of the design criteria for the procurement of the Next Generation Mechanized Roll Powder Facility. Work was divided into two major areas of effort, namely:

1. Small-scale studies, either in the laboratory or using production equipment, to evaluate proposed changes to the existing process or equipment.
2. Preparation of design criteria drawings and specifications for the buildings and major AMC equipment.

Six small-scale studies designated A-2 through A-7 in the Program Plan (see Appendix) were conducted as a part of this project. Detailed results of these studies are found in the first section of this report.

Preparation of drawings and specifications was divided into ten major tasks, identified as B-1 through B-10 in the Program Plan. The second section of this report describes each task and includes either a specification or a list of drawings generated under this project. Copies of drawings are not included in this report.

DISCUSSION

Investigation of new process or equipment technology conducted under this project included the following: 1) Feasibility of using a continuous moisture analyzer for control purposes, 2) Evaluation of a modified radiation pyrometer as a temperature sensor, 3) Feasibility of carpet roll strip cooling with air in lieu of water, 4) Determination of drying characteristics of pre-roll sheets, 5) Testing of improved conveyor belt materials, and 6) Feasibility of increasing final roll capacity. The areas selected for study were based on a review of the performance of the prototype Mechanized Roll unit over a period of years. Improvements in safety, quality, and capacity were the prime objectives.

The prototype Mechanized Roll unit built during the 1950's deviates from present-day safety requirements in certain areas. In preparing the building and equipment drawings and specifications, particular attention was paid to assure compliance with current safety and pollution standards. Rearrangement of equipment was made to provide improved operator protection. Major areas affected were wall material of construction, electrical equipment, lighting, and venting.

CONCLUSIONS AND RECOMMENDATIONS

As a result of the laboratory and small-scale tests conducted under this project, the following features have been incorporated in the design of the Next Generation Mechanized Roll Facility:

1. Anacon Model 106 Continuous Moisture Analyzer for control of paste feed.

2. A Bristol radiation pyrometer, with modifications to protect it in the pre-roll bay environment, for monitoring sheet temperature.

3. A dwell bay for drying of the pre-roll sheet by convection with heated air.

4. An ambient air cooling bay in combination with a refrigerated compartment for cooling of the carpet roll strip.

FUTURE WORK

Three belt materials were selected for full-scale evaluation. One type, Durapol, has proven unsatisfactory, the other two are undergoing long-term testing on the prototype production unit. Results of these tests will be used for future designs.

Task A-2

Feasibility Study of a Continuous Moisture Analyzer

Digest

Objective

The moisture content of propellant paste varies appreciably between blends and to a lesser extent within blends. The amount of paste charged to the pre-roll is adjusted by the operator in accordance with an analysis of a sample from the blender made by the paste moisture laboratory. Improved control over charge weights would result from having a continuous moisture analyzer incorporated into the mechanized roll process. This test is to determine if a continuous moisture analyzer would be feasible in this application.

Summary of Results

An Anacon Model 106 continuous moisture analyzer was tested in the laboratory to determine its accuracy and operating characteristics under simulated operating conditions. Since no moisture standard was available for calibration, the instrument readings were compared with samples analyzed by the distillation (with CCl_4) method or the blower method. In the range from 4% to 14% moisture the variation was found to be ± 0.68% when compared with the distillation method and 1.14% when compared to the blower method.

Variation in readings was checked under varying environmental conditions. Light reflection, height of the instrument above the sample, and pressure above 4 psig in the instrument case were found to cause a significant change in instrument readings. Ambient temperature variation and compacting the sample had very little effect.

Conclusion

Based on the results of this test, the continuous moisture analyzer will provide results more accurate than the blower method and slightly less accurate than the distillation method in the moisture range from 4% to 14%. It will result in better control of the charge weight than the present method due to the continuous analysis it provides. The present method does not compensate for variations within paste blends.

It is recommended that a continuous moisture analyzer of the type tested be incorporated into the design of the next generation of the Mechanized Roll.

Feasibility Study of a Continuous Moisture Analyzer

Introduction

The use of a continuous moisture analyzer to control the charge weight would offset the effect of variations in moisture which are evident in the present operation. A single sample taken from the blender is analyzed at the moisture laboratory and any necessary adjustments are made in the charge weight by the operator under present practice. Variations within the blend and between charges cannot be compensated for. A more uniform product from the Mechanized Roll would result if the moisture in the material fed to the rolls is monitored on a continuous basis. The moisture readings could be used to control charge weights so that the weight of the propellant sheet on the preroll at the end of the cycle would remain constant.

The procurement and laboratory testing of a continuous moisture analyzer was accomplished under this task. A continuous test in the present Mechanized Roll Facility was not made because there is no suitable location available for installing a moisture analyzer. The sensor tested appeared to have adequate protection from production hazards through its sealed, insulated, and air-purged case.

Discussion of Results

A search of various sources of information on moisture analyzers resulted in the selection of an infrared, reflecting, non-contact type instrument with a sealed and air-purged sensor. These features were considered essential to the use of a moisture analyzer on a continuous basis in a production facility. An instrument similar to the one selected had been used in a laboratory at Picatinny Arsenal for the past two years. The instrument selected for this test was the Anacon Model 106.

A thorough laboratory test was accomplished in order to determine sensitivity, accuracy, precision, and the effect of environmental conditions. The accuracy of the test was dependent on the precision of other laboratory tests which were used to determine paste moisture. No material which could be used as a standard was available. The only method which could be used to determine accuracy was a statistical comparison of the results obtained with the continuous moisture analyzer and the blower and distillation (CCl_4) methods. Tables I and II show the results of this comparison.

The complete laboratory report is included in Appendix A. Table I of the laboratory report shows that the sensitivity was doubled when the moisture range measured was narrowed from 15% to 10%. This resulted in the variation from the mean being reduced from ± 1.16% to ± 0.68%. The accuracy of the distillation method was determined by the laboratory to be ± 0.5%. Thus the continuous moisture analyzer appears to be only slightly less accurate than the distillation method in the range from 4% to 14% moisture.

When the same instrument settings were used for samples analyzed by the blower method, the variation increased to ± 1.14%. These results indicate the continuous moisture analyzer is more accurate than the blower method under the conditions of this test.

The effect of changes in test conditions was determined. Changes in illumination above 40 foot-candles and in the distance between the sensor and the surface of the sample were found to cause variations. The height of 4½ inches used in the regular tests was satisfactory. Compacting the sample did not affect meter readings significantly. Temperature variations between 75 and 95°F did not affect the readings. When the sensor was pressurized to 4 psig, the readings averaged approximately 0.5% lower than before. Refer to the laboratory report for a description of these tests.

Conclusions and Recommendations

A. Conclusions

In a laboratory test the Anacon Model 106 showed an overall variation of ± 0.68% moisture when compared to the distillation method of analysis in the moisture range from 4% to 14%.

Small variations in light, temperature, and sample compactness did not change the instrument readings.

Changes in the height of the instrument above the sample and in the pressure of the case above atmospheric caused appreciable changes in readings.

B. Recommendations

It is recommended that the Anacon Model 106 continuous moisture analyzer or any equivalent unit be incorporated into the design of the next generation of the Mechanized Roll Facility as a means of adjusting the charge weight of paste being fed to the rolls.

The unit should be calibrated against a standard paste sample and used under constant operating conditions of light, pressure, and sample distance from the sensor in order to insure consistent results in a production facility.

TABLE I

Feasibility Study of a Continuous Moisture Analyzer

Comparison of continuous moisture analyzer readings with distillation (CCl_4) method in the range of 4% to 14% moisture in N-5 paste.

Sample No.	Meter Reading	Analyzer Result % Moisture	Distillation Method % Moisture
1	68	13.95	13.96
2	51	9.90	10.04
3	69	14.30	14.26
4	27	6.10	6.06
5	32	6.82	7.13
6	38	7.85	7.78
7	13	3.85	4.50
8	44	8.78	8.87
9	46	9.00	9.04
10	48	9.36	8.40
11	46	9.00	8.45
12	40	8.05	7.99
13	38	7.80	7.72

Test Accuracy ± 0.68% at 95% Confidence Level.

TABLE II

Feasibility Study of a Continuous Moisture Analyzer

Comparison of continuous moisture analyzer readings with blower method in the range of 6% to 14% moisture in N-5 paste.

Sample No.	Meter Reading	Analyzer Result % Moisture	Blower Method % Moisture
1	40	7.15	8.0
2	30	6.14	7.1
3	51	8.29	8.9
4	47	7.87	8.2
5	88	12.11	13.1
6	50	8.18	8.0
7	56	8.80	8.1
8	48	7.97	7.8
9	57	8.90	8.3
10	53	8.48	8.3
11	58	9.00	8.8
12	44	7.55	8.0
13	56	8.80	8.5
14	71	10.44	11.1
15	61	9.31	10.1
16	52	8.39	8.2
17	42	7.35	6.3
18	61	9.31	9.0
19	50	8.18	7.6
20	66	9.84	10.1
21	61	9.31	9.1
22	67	9.93	10.1
23	60	9.20	9.1
24	58	9.00	8.6
25	74	10.65	11.5
26	76	10.86	11.0
27	70	10.24	9.6
28	77	10.96	10.4
29	69	10.14	8.9

Test Accuracy ± 1.14% at 95% Confidence Level.

Task A-3

Testing of a Temperature Sensor for the Pre-Roll

Digest

Objective

The temperature of the propellant on the pre-roll mill is monitored with a radiation pyrometer. The original unit contained a thin plastic window and the temperature readings became erratic soon after its installation due to moisture reaching the thermopile. A second unit was installed with a glass filter over the plastic window to protect it, but this arrangement resulted in decreased sensitivity. The purpose of this task was to determine if another type radiation pyrometer would improve this operation and to test the one selected as the most likely candidate.

Summary of Results

A literature search verified the fact that a thermopile sensor is the preferred type for temperatures below 250°F. A screening of information from vendors indicated that the sensing elements in most thermopile instruments were essentially the same as the Bristol instrument in the Mechanized Roll Facility, except that some of them used a lens for focusing the infrared (IR) beam onto the thermopile elements. An arsenic trisulfide lens from a thermopile temperature sensor was obtained and tested in the pre-roll bay environment. It was attacked by the paste ingredients and cracked under the heat from a roll fire. The surface was discolored and pitted.

A laboratory test was conducted on a Bristol instrument and showed that the use of the glass filter was undesirable. This instrument gave accurate readings between $150^{o}F$ and $250^{o}F$ when a polyethylene window was used. Several other window materials were tested and a 4-mil thick polyethylene sheet was selected as the best IR transparent material.

At this point the problem of adequate protection of the sensor in the pre-roll bay environment was considered. A housing extension, adapter, and air purge were designed, installed, and tested in the pre-roll bay. The resulting arrangement provided reliable temperature monitoring over a week of continuous operation without a window change. Also it provided a unit in which the window could be changed without removing the sensor. Now the window can be changed during any scheduled roll cleaning period with a delay of only 10 to 15 minutes.

Conclusion

Based on the results of this study it is recommended that the Bristol radiation pyrometer, with modifications to protect it in the pre-roll bay environment, be used in the next generation of Mechanized Roll Facilities.

Testing of a Temperature Sensor for the Pre-Roll

Introduction

In the operation of a Mechanized Roll it is desirable to monitor the propellant temperature while it is on the pre-roll mill. The maximum temperature reached by the propellant on the pre-roll correlates with the moisture content of the product and is related to roll speed, gap settings, charge weights, paste temperature, cycle time, and paste rolling or colloiding characteristics.

The first radiation pyrometer unit installed in the present Mechanized Roll Facility lost some of its accuracy and sensitivity after short periods of operation due to condensate collecting on the plastic window and water reaching the thermopile during roll fires. This was a Bristol instrument using a Veletron 9E7 sensor. When a new unit, of the same type, was installed in August 1967, a glass filter was placed over the plastic window for protection. This arrangement resulted in reduced sensitivity. After a short period of operation a build-up of condensate on the filter reduced the accuracy and sensitivity even further. In addition, the filter cracked frequently due to roll fires and several hours of downtime were required for replacement. As part of this Production Engineering Project it was proposed that a search be made for an improved type of radiation pyrometer that could withstand the environment of the pre-roll bay and provide accurate and reliable readings over long periods of continuous operation.

Discussion of Results

A search of the literature on radiation pyrometry verified the fact that a thermopile sensor with a temperature compensation element is the preferred type of unit for the temperature range of 180°F to 250°F, which is required by the pre-roll. Information contained in brochures for this type of instrument from several vendors revealed that the only type of sensor essentially different from the unit in use on the pre-roll mill was one with a lens that would focus the IR radiation onto the thermopile. This feature would permit the unit to be placed farther from the roll than is possible with the present unit. An arsenic trisulfide lens from this type unit was obtained for testing in the pre-roll bay environment.

It was found that the arsenic trisulfide lens was attacked by the paste dust and/or condensate and was easily cracked from thermal shock even when it was recessed in an aluminum tube. Because of the results of this test it was decided to modify the installation of the present unit before considering another type unit. The problem of protecting the lens from dust, condensate, heat from roll fires, and water from the sprinkler system would have to be solved regardless of the type of sensor used. The cost of a lens and downtime required for replacing it were considered also.

Laboratory tests were conducted to evaluate the performance of the Bristol radiation pyrometer that was being used on the pre-roll and to test materials that might be used for a window to replace the filter. A preliminary test showed that the filter being used to protect the plastic window affected the accuracy and sensitivity of the sensor. Of the materials tested, polyethylene showed the least variation from a standard temperature in the 150°F to 250°F temperature range. It was determined that 4-mil thick polyethylene would provide a satisfactory window material for the Bristol instrument. A copy of the laboratory report is in Appendix A.

An extension to the sensor housing was designed with an enlarged slide gate. The diameter of the slide gate opening was based on values for the angle of divergence furnished by the manufacturer. This extension was attached to the sensor housing with an adapter that also served as a retainer ring for the lens holder. This arrangement permitted the lens to be replaced "in place". The adapter was knurled on the outside edge so that it could be removed by hand.

After the sensor was installed on the pre-roll with the extension attached, it was found that the air purge at the mouth of the slide gate did not prevent condensate from entering the housing extension and coating the window. The results are shown in Figure 2. To correct this condition, a groove was machined around the adapter, eight holes were drilled from the groove into the interior chamber, and a cover plate with an air inlet was placed over the groove. This provided an air screen immediately in front of the lens that prevented dust and condensate from coating the lens.

The effect of the above design changes are shown by a comparison of the recorder traces under different conditions (See Figures 1 thru 3). With the final arrangement, consistent and accurate readings were recorded over several days of continuous operation as shown in Figure 3. The lens should be replaced about once each week to correct for variation due to the environment and after each roll fire. The window replacement does not require removing and reinstalling the sensor and can be accomplished in approximately 10 minutes. With the previous arrangement the window replacement required that the sensor be removed and resulted in at least two hours of downtime.

Conclusions and Recommendations

A. Conclusions

As a result of the accomplishments of Task A-3 of this project, the following facts were established:

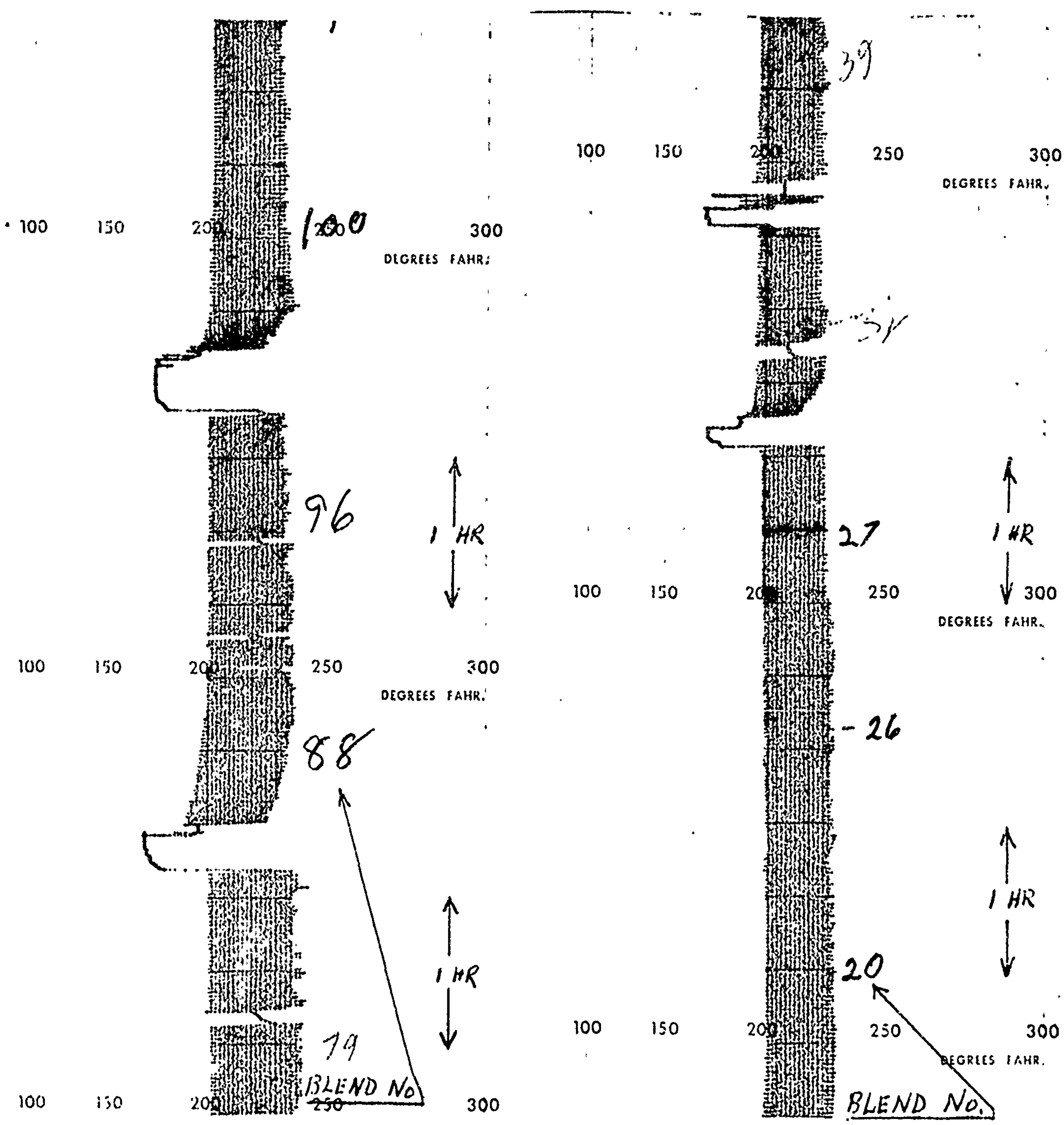
1. A thermopile sensor such as the Veletron Model 9E7 is accurate and reliable in the temperature range from 180°F to 250°F.
2. An instrument with a glass filter or arsenic trisulfide lens is undesirable for use in the pre-roll bay due to the sudden temperature changes due to roll fires and the environmental effects of paste dust or condensate on the lens surface.
3. Of the plastic materials tested, polyethylene is the one recommended for use as a window for the Veletron 9E7 sensor.
4. The use of a housing extension, slide gate, and air purge is effective in protecting the sensor from excess heat, water, dust, and condensate.
5. With the above modifications made on the present temperature sensing unit, satisfactory monitoring of the pre-roll propellant sheet with a radiation pyrometer has been demonstrated over a period of three months of normal operation.

B. Recommendations

It is recommended that a Bristol instrument with a Veletron 9E7 sensor, together with the modifications made under Task 3 of this project, be used for monitoring the pre-roll temperatures of the next generation of Mechanized Roll Facilities.

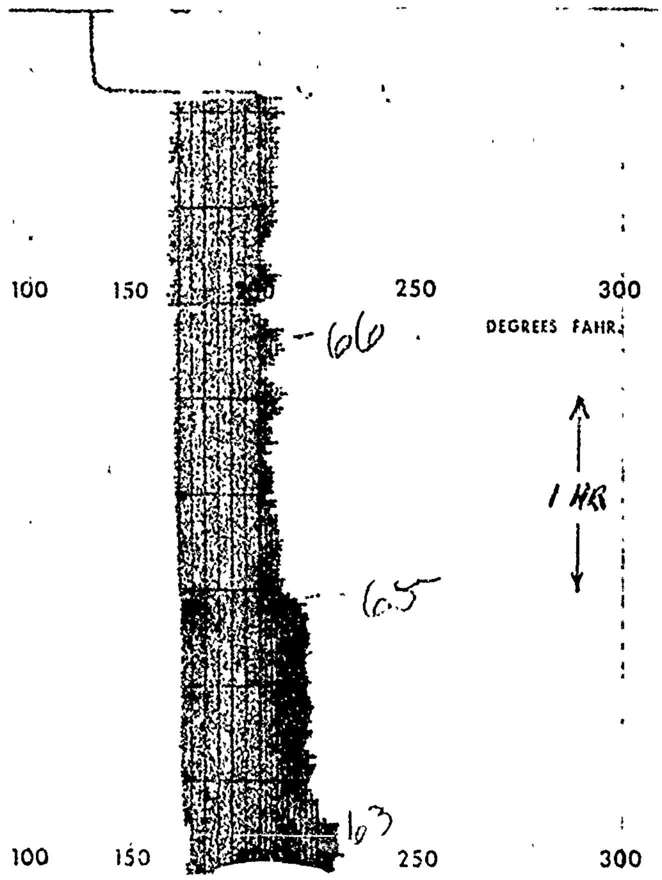
Testing a Temperature Sensor for the Pre-Roll

Figure 1. Effect of a Glass Filter Over the Window of the Veletron 9E7 Sensor on Instrument Readings. (Bristol Instrument with 9E7 Sensor)

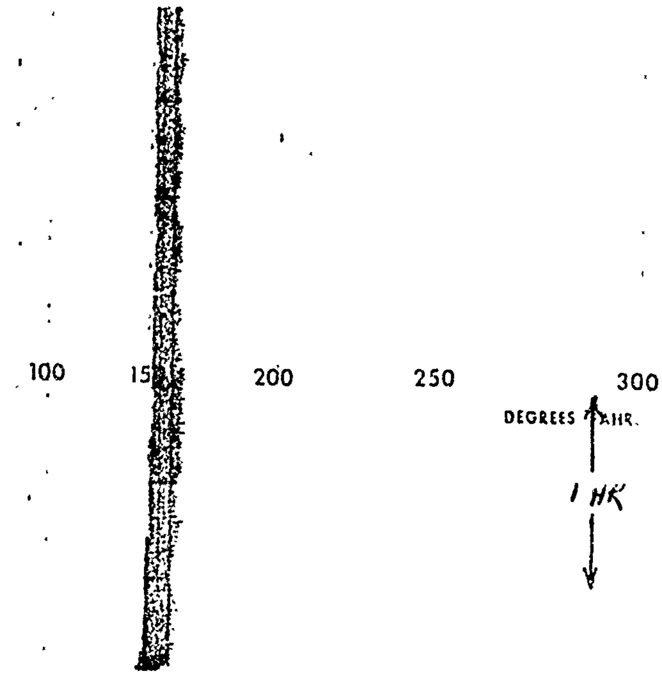


Normal Operation Over a Period of One Week (Filter Cleaned During Each Shut-down for Roll Cleaning)

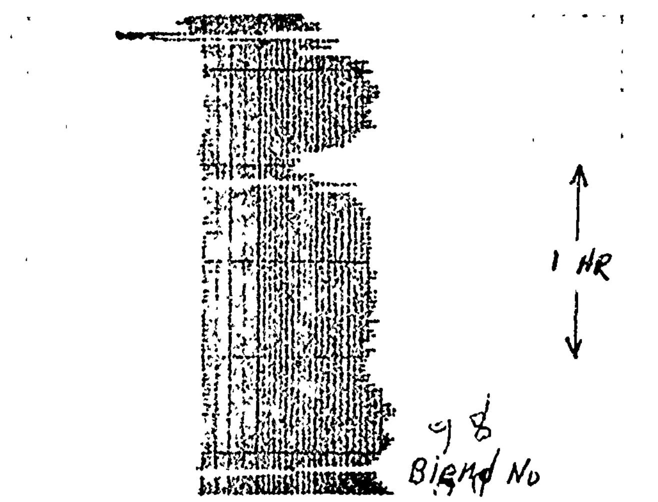
Figure 2. Effect of Condensate on the Plastic Window without an Air Purge on Instrument Readings (Bristol Instrument with 9E7 Sensor)



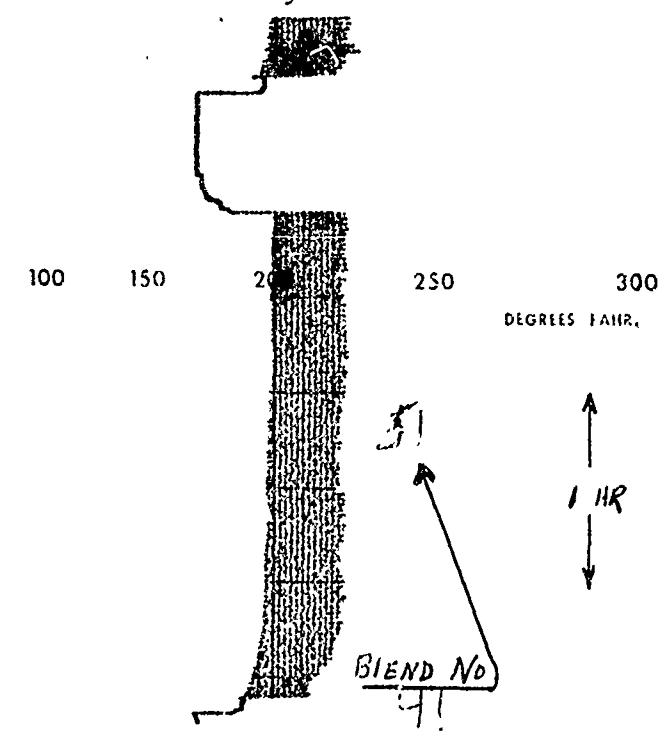
24 Hours After Initial Operation



At End of Three Days



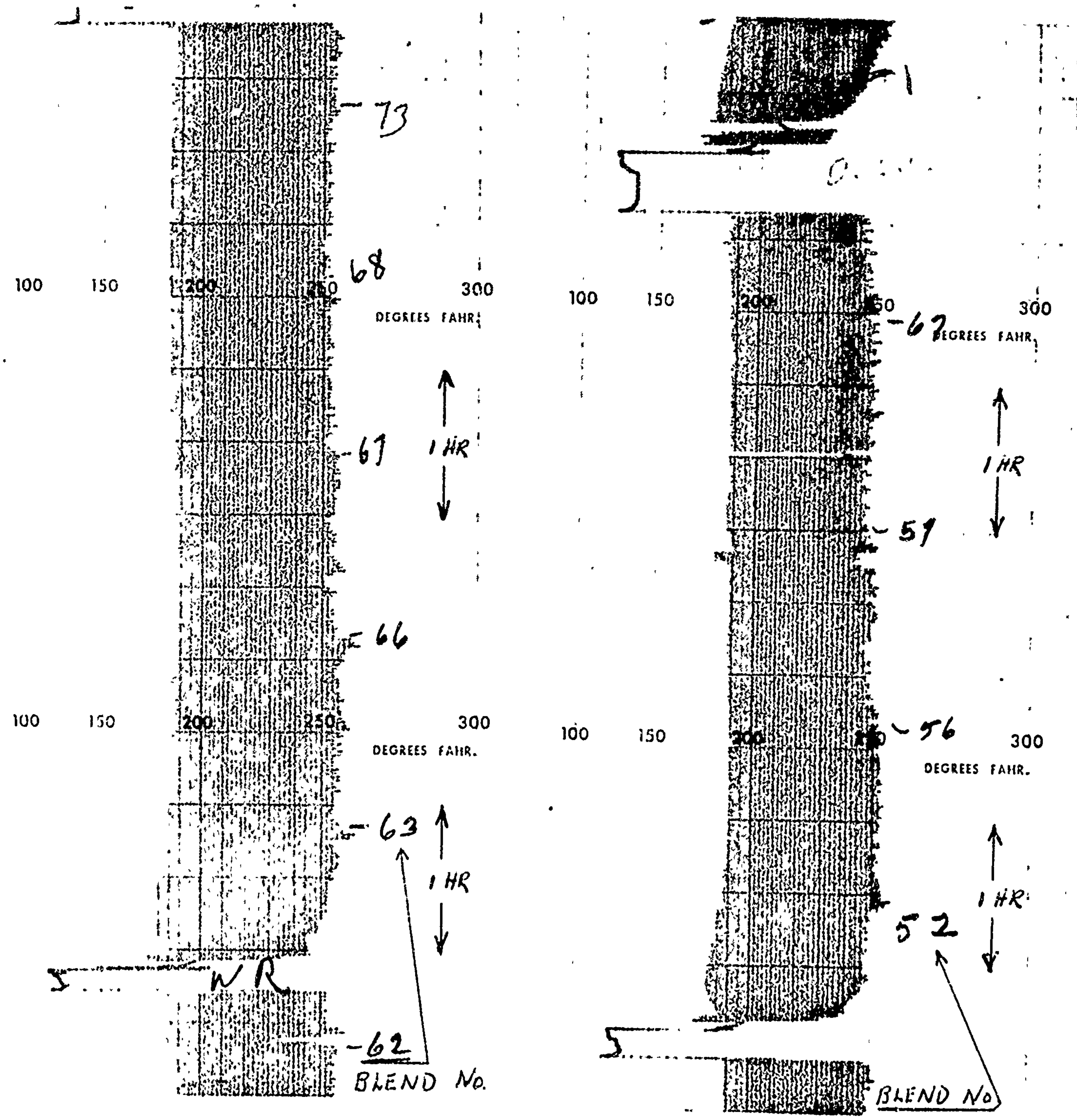
Initial Readings



48 Hours After Initial Operation

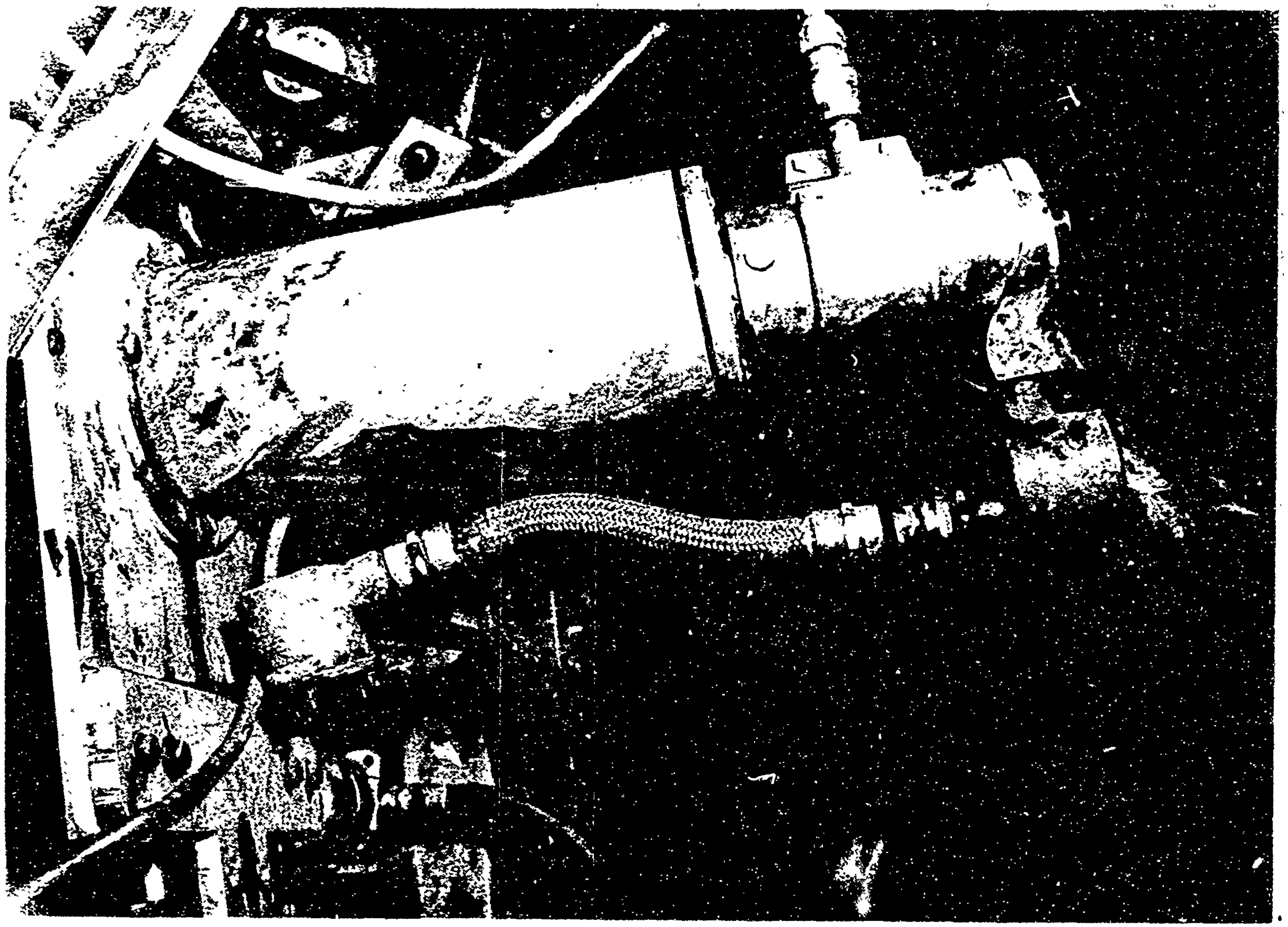
Testing a Temperature Sensor for the Pre-Roll

Figure 3. Effect of Air Purge with a Plastic Window and Housing Extension on Instrument Readings.



Initial Readings

After 7 Days of Normal Operation



NO. 4. VELETRON 9E7 TEMPERATURE SENSOR WITH MODIFICATIONS TO PROTECT THE PLASTIC WINDOW

Task A-4

The Feasibility of Cooling an N-5 Propellant Carpet Roll Strip with Air

Digest

Objective

This test was conducted in order to determine if the N-5 carpet roll strip can be cooled to below 100°F with air in lieu of the water bath, prior to winding. The water bath leaves a wet surface on the carpet roll strip that is difficult to remove. An eight-hour rest period is used to finish the drying process. An air drying process would eliminate this rest period.

Summary of Results

A laboratory test was conducted so the drying characteristics of the N-5 propellant could be determined. From the laboratory data and data from a test in the final roll bay of the Mechanized Roll Facility, the cooling rates at various air flow rates and temperature differences were derived. From these, the cooling rate curves were plotted to show time of exposure necessary to cool a propellant strip from 190°F to 100°F. The strip length or cooling compartment length was calculated from the time of exposure. Using air cooled to 50°F the minimum length of the cooling compartment was 24 feet for a production rate of 800 pounds per hour.

In order to cut the required length of the cooling compartment, the use of a combination of ambient air cooling plus a refrigerated plate cooler appears promising. A calculation was made to estimate the temperature and required length of a cooler to cool the strip from 150°F to 100°F, and a length of eleven feet was obtained.

Conclusion

From the results of this test, it was determined that a cooling compartment at least 24 feet long is required to cool a carpet roll strip to less than 100°F with air cooled to 50°F. In order to reduce this length, it was proposed that an additional test with a refrigerated plate be conducted.

It is recommended that a combination of ambient air cooling with a blower and a refrigerated compartment be used in lieu of the water bath, provided the cooling test with the cold plate is successful.

The Feasibility of Cooling an N-5 Propellant Carpet Roll Strip with Air

Introduction

In order to wind the propellant strip into carpet rolls after it leaves the final roll mill it has to be cooled to a temperature of 100°F or less. In the present facility the cooling is accomplished by immersing the strip in a water bath. The temperature of the water is controlled at about 90°F through the use of a heat exchanger, temperature sensor, and circulating pump. This process uses a squeegee and a series of air jets with heated air to remove the moisture from the surface of the strip. Cooling the strip by immersion is satisfactory for controlling the strip temperature but the surface moisture is difficult to remove completely and wet carpet rolls cause voids in the pressed grains. In order to minimize this discrepancy the carpet rolls are stored in a heated rest house for eight hours before being fed to the presses.

Cooling the strip with air would eliminate the drying problem and the need to store the carpet rolls before pressing. The feasibility of cooling the final roll strip with air was selected as one of the tasks authorized under PE 105 of the Mechanized Roll Improvement Program. This task was designed to determine the cooling characteristics of the propellant strip by laboratory tests and a full scale test in the Mechanized Roll Facility.

Discussion of Results

The cooling characteristics of the propellant strip and the amount of cooling that can be expected with different air velocities and temperatures were determined in the laboratory tests. The complete laboratory report and photo-graphs are included in the appendixes. The rate of cooling at different air velocities is plotted against log mean temperature differences (ΔT_{LM}) in Figure 1 from the laboratory data. Since the rate of cooling gives a straight line, corresponding values of ΔT_{LM} can be used for calculating temperatures vs. time curves for any range of temperatures provided the air velocity and environmental factors remain constant.

The ability to cool the final roll strip from 190°F to 100°F was found to be the requirement for the cooling unit. The 190°F temperature was determined by a measurement of the strip temperature at the point where the final roll strip emerges from the final roll bay. The 100°F temperature has been determined as the maximum temperature at which the carpet roll strip can enter the winder to give acceptable carpet rolls. Propellant strip at temperatures above this value produces a carpet roll with a bulge in the center when wound on the present automatic winder.

Figure 2 is a plot of temperature vs. exposure time derived from corresponding ΔT_{LM} values from Figure 1. The four curves give a comparison of the results that would be expected in an air cooling unit at two values of air flow rates and two cooling air temperatures at each flow rate. From the production rate of the propellant strip by the Mechanized Roll, the length of strip that corresponds to the time of exposure can be determined. The length of strip per minute corresponds to the final roll speed in feet per minute and is shown for various production rates in Figure 3.

Figure 4 is similar to Figure 2 and represents cooling results from the full scale test runs in the final roll bay of the Mechanized Roll Facility. The exposure times were calculated from ΔT_{LM} values taken from Figure 1.

As before, cooling rates with air temperatures other than those used in the test can be derived from corresponding ΔT_{LM} values. The plot of the exposure times shown in Figure 4 was made for air at $50^{O}F$ to show the effect of using conditioned air for cooling. Fifty-degree air is close to the practical limit for cooling the required volume of air from a $100^{O}F$ ambient temperature without recirculation.

The results of this test indicate that at least twenty-four feet of propellant strip must be exposed to air at $50^{O}F$ in order to cool it from $190^{O}F$ to $100^{O}F$. When a ΔT_{LM} of less than $60^{O}F$ is used, the rate of cooling is not sufficient to warrant the space required in a continuous process. This is evident by the slope of the cooling curve below the point corresponding to a ΔT_{LM} of $60^{O}F$. This point corresponds to the $110^{O}F$ strip temperature on the $50^{O}F$ air temperature curve and $142^{O}F$ strip temperature on the $82^{O}F$ air temperature curve.

Cooling of the final roll strip with ambient air of the volume used in this test appears feasible for reducing the temperature from $190^{O}F$ to less than $150^{O}F$. To cool it below this temperature another type of cooling chamber will be required.

The preliminary calculation for a refrigerated plate type of cooler was made in order to give a rough estimate of its required length and operating temperature. Using an estimated 40 BTU per square foot per degree per hour for the coefficient, and a plate temperature of $20^{O}F$, the calculated length of strip at a 44 FPM final roll speed would be about eleven feet long. The capacity was calculated for a production rate 20% above the production rate of the present Mechanized Roll Facility.

Conclusions and Recommendations

A. Conclusions

From the results of this test the following facts were established:

1. The length of a cooling unit using air at 80°F would approximate 46 feet, and when the air is cooled to 50°F, this would be reduced to 24 feet at a production rate of 800 pounds per hour.

2. The air flow rate has an appreciable effect on the cooling rate.

3. The propellant strip can be cooled to less than 150°F with ambient air in less than 10 feet. Cooling by this method on the final roll conveyor followed by a refrigerated plate type cooler to reduce the temperature to less than 100°F appears to be possible from preliminary calculations.

B. Recommendations

It is recommended that a cooling test be conducted with a refrigerated plate to determine if sufficient cooling can be obtained in twelve feet of contact to reduce the propellant temperature from 150°F to 100°F.

If this test is successful, it is recommended that air cooling of the propellant strip be incorporated into the design of the next generation of Mechanized Roll Facility in place of the water bath.

TABLE I

Design Engineering for Next Generation of Mechanized Roll Facility

Cooling Rate of N-5 Carpet Roll with Variation in ΔT_{LM}* at Constant Air Flow Rates

(From Laboratory Data)

A. At Flow Rate of 5 CFM (Flowmeter Reading)

ΔT_{LM} (°F)	Cooling Rate (°F/Sec)
23	0.11
36	0.22
56	0.40
76	0.53
94	0.71

B. At Flow Rate of 15 CFM (Flowmeter Reading)

ΔT_{LM} (°F)	Cooling Rate (°F/Sec)
13	0.11
28	0.23
33	0.27
42	0.39
52	0.61
78	0.86
106	1.44

C. At Flow Rate of 25 CFM (Flowmeter Reading)

ΔT_{LM} (°F)	Cooling Rate (°F/Sec)
23	0.25
36	0.55
56	1.11
76	1.50
95	1.88

* ΔT_{LM} is the log mean difference in temperature readings between the cooling air and the N-5 propellant sample.

TABLE II

Design Engineering for Next Generation of a Mechanized Roll Facility

DATA SUMMARY
(Full Scale Test)

A. Cooling With Air at 650 CFM Flow Rate

Run No.	Air Temp. (°F)	Roll Speed (FPM)	Exposure Time (Sec)	Initial Temp. (°F)	Final Temp. (°F)	Cooling Rate (°F/Sec)	ΔT_{LM} (°F)
1	77	32	11.25	[illegible]	164.7	3.42	105.8
2	77	20	18.0	203.2	153.7	2.75	99.5

B. Cooling With Air at 325 CFM Flow Rate

Run No.	Air Temp. (°F)	Roll Speed (FPM)	Exposure Time (Sec)	Initial Temp. (°F)	Final Temp. (°F)	Cooling Rate (°F/Sec)	ΔT_{LM} (°F)
1	75	30	12.00	197.6	171.7	2.15	109.0
2	70	32	11.25	201.3	173.7	2.45	116.8
3	77	32	11.25	206.3	176.7	2.63	113.8

TABLE III

Design Engineering for Next Generation
of a Mechanized Roll Facility

Cooling Rate Curves for N-5 Propellant with Two Air Temperatures and Three Air Velocities

(From Laboratory Data)

A. Air Temperature of 82°F. and Flowmeter Reading of 5 CFM

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 165	94.5	0.70	36	36
165 to 150	75.0	0.56	27	63
150 to 126	55.0	0.42	57	120
126 to 110	36.0	0.21	76	196
110 to 100	23.0	0.11	91	278

B. Air Temperature of 82°F. and Flowmeter Reading of 15 CFM

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 165	94.5	1.22	20	20
165 to 150	75.0	0.88	17	37
150 to 130	55.0	0.63	32	69
130 to 120	42.0	0.38	26	95
120 to 110	32.0	0.26	38	133
110 to 100	23.0	0.20	50	183

C. Air Temperature of 82°F. and Flowmeter Reading of 25 CFM

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 165	94.5	1.92	13	13
165 to 150	75.0	1.47	10	23
150 to 130	56.0	1.04	19	42
130 to 120	42.0	0.72	14	56
120 to 110	32.0	0.48	21	77
110 to 100	23.0	0.28	36	113

D. Air Temperature of 50°F. and Flowmeter Reading of 15 CFM

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 165	128.0	1.72	15	15
165 to 150	108.5	1.43	10	25
150 to 130	89.0	1.15	17	42
130 to 120	74.0	0.91	14	56
120 to 110	65.0	0.73	14	70
110 to 100	55.0	0.62	16	86

E. Air Temperature of 50°F. and Flowmeter Reading of 25 CFM

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 165	128.0	2.70	9	9
165 to 150	108.5	2.27	7	16
150 to 130	89.0	1.81	11	27
130 to 120	74.0	1.45	7	34
120 to 110	65.0	1.22	8	42
110 to 100	55.0	1.02	10	52

TABLE IV

Design Engineering for Next Generation
of a Mechanized Roll Facility

Cooling Rate Curves for N-5 Propellant at Two Air Velocities and Two Temperatures from Full Scale Test Data

A. Air Temperature of 80°F. and Full Air Flow from 650 CFM Blower

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 170	99	3.15	6	6
170 to 150	79	2.45	8	14
150 to 130	58	1.72	12	26
130 to 120	45	1.25	8	34
120 to 110	35	0.90	11	45
110 to 100	25	0.55	18	63

B. Air Temperature of 80°F. and Half Air Flow from 650 CFM Blower

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 170	99	2.02	10	10
170 to 150	79	1.55	13	23
150 to 130	58	1.10	18	41
130 to 120	45	0.80	13	54
120 to 110	35	0.57	18	72
110 to 100	25	0.35	29	99

C. Air Temperature of 50°F. and Full Air Flow from 650 CFM Blower

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 170	129	4.30	5	5
170 to 150	109	3.50	6	11
150 to 130	89	2.80	7	18
130 to 120	74	2.30	4	22
120 to 110	65	1.95	5	27
110 to 100	55	1.60	6	33

D. Air Temperature of 50°F. and Half of Air Flow from 650 CFM Blower

Strip Temperature (°F)	ΔT_{LM} (°F)	Cooling Rate (From Fig. 1) (°F/Sec)	Time Required (Sec)	Time Accumulated (Sec)
190 to 170	129	2.75	7	7
170 to 150	109	2.25	9	16
150 to 130	89	1.85	11	27
130 to 120	74	1.45	7	34
120 to 110	65	1.25	8	42
110 to 100	55	1.02	10	52

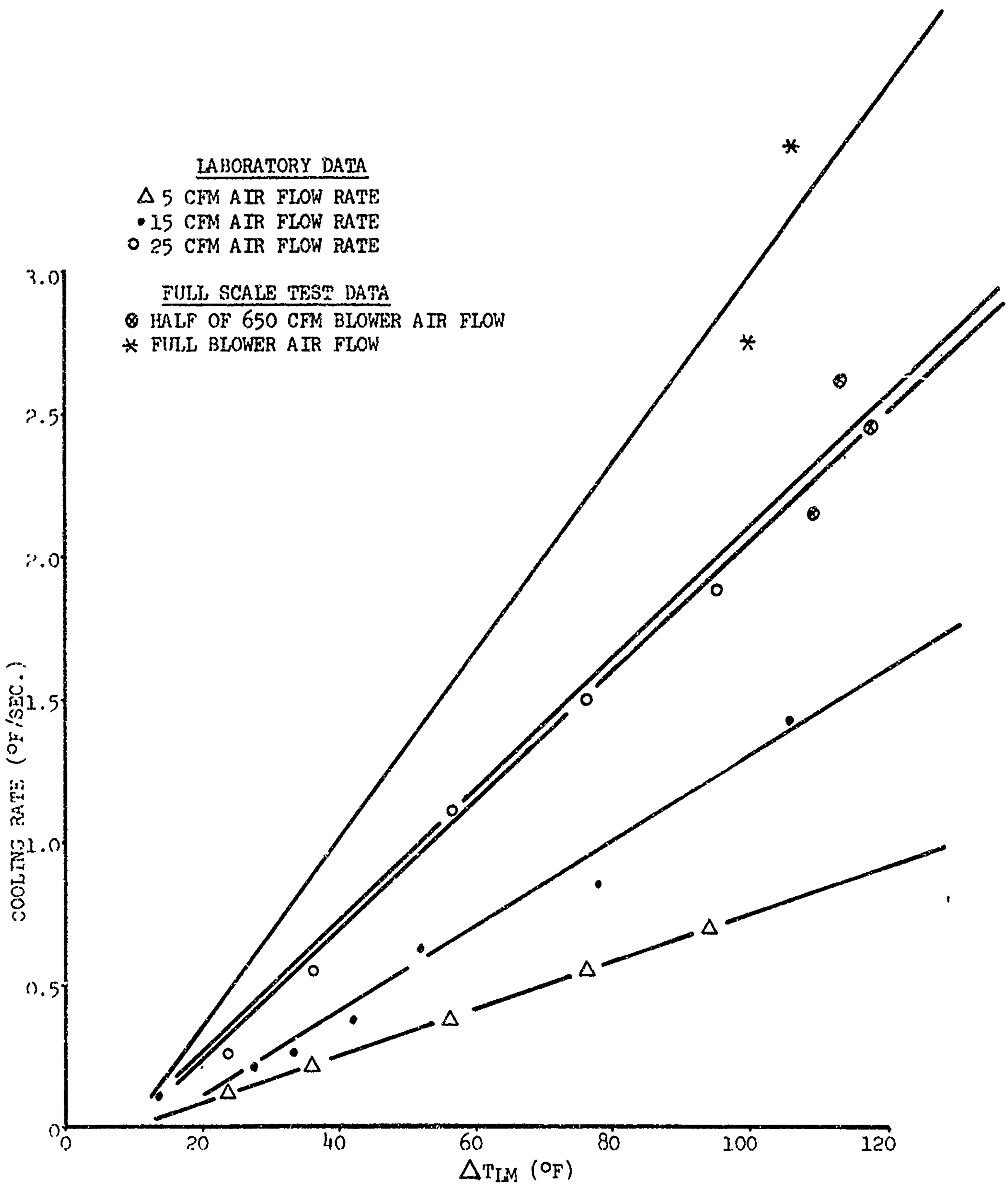


FIGURE 1
COOLING N-5 CARPET ROLL STRIP WITH AIR COOLING RATE VS TEMPERATURE DIFFERENCE

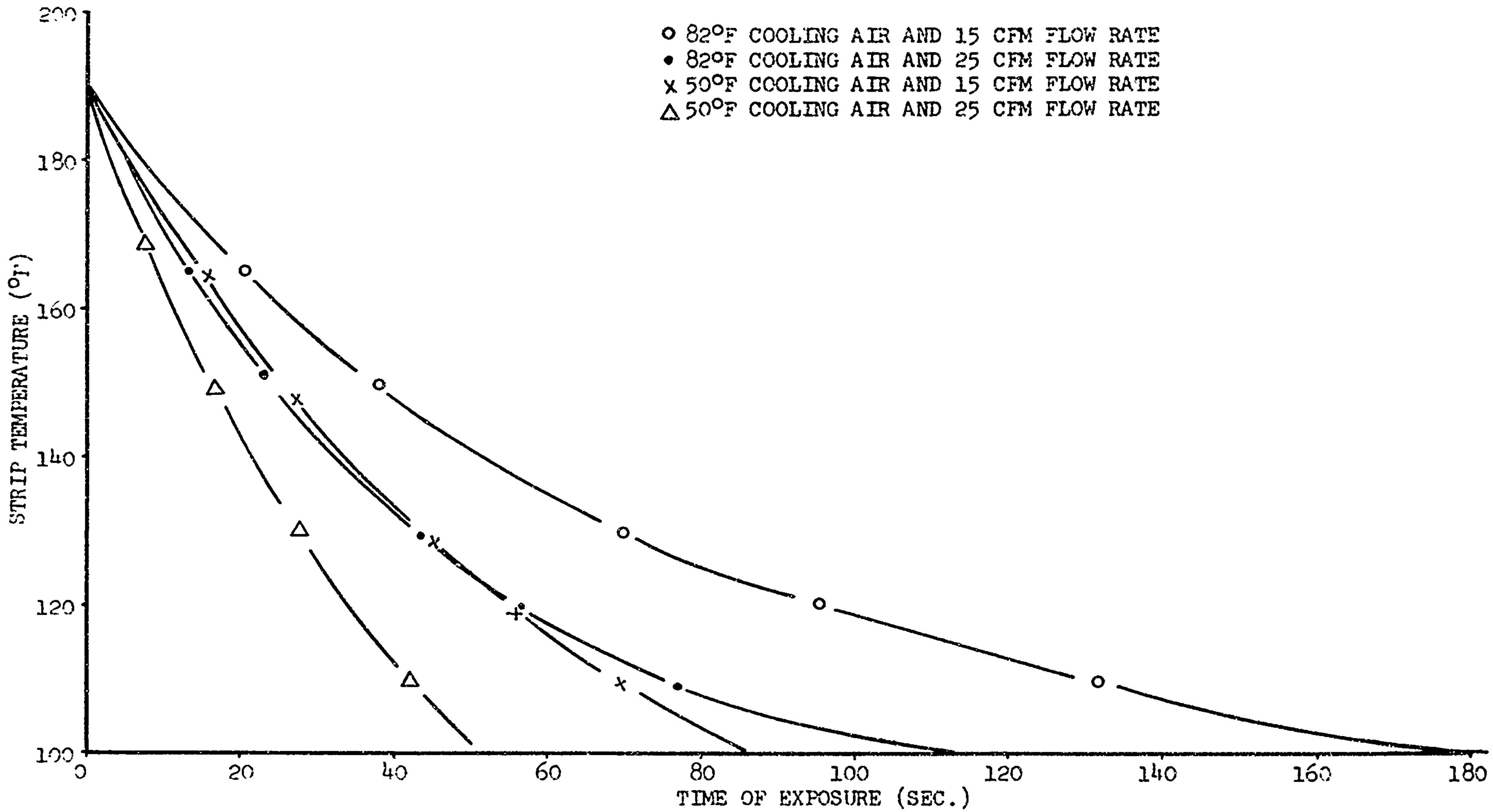


FIGURE 2
COOLING N-5 CARPET ROLL STRIP WITH AIR, LABORATORY DATA COOLING RATE CURVES

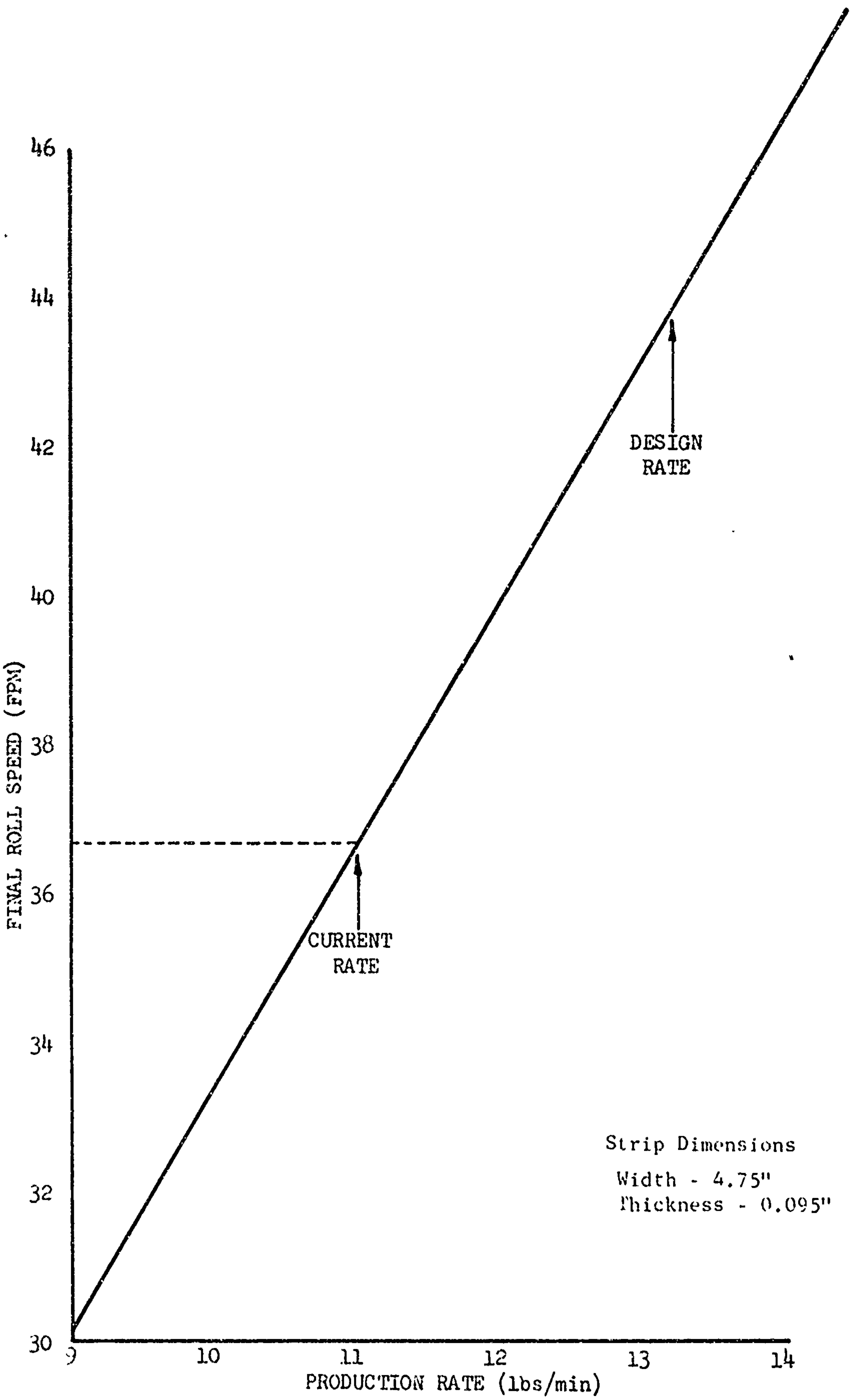


FIGURE 3
MECHANIZED ROLL FINAL ROLL MILL ROLL, SPEED VS PRODUCTION RATE

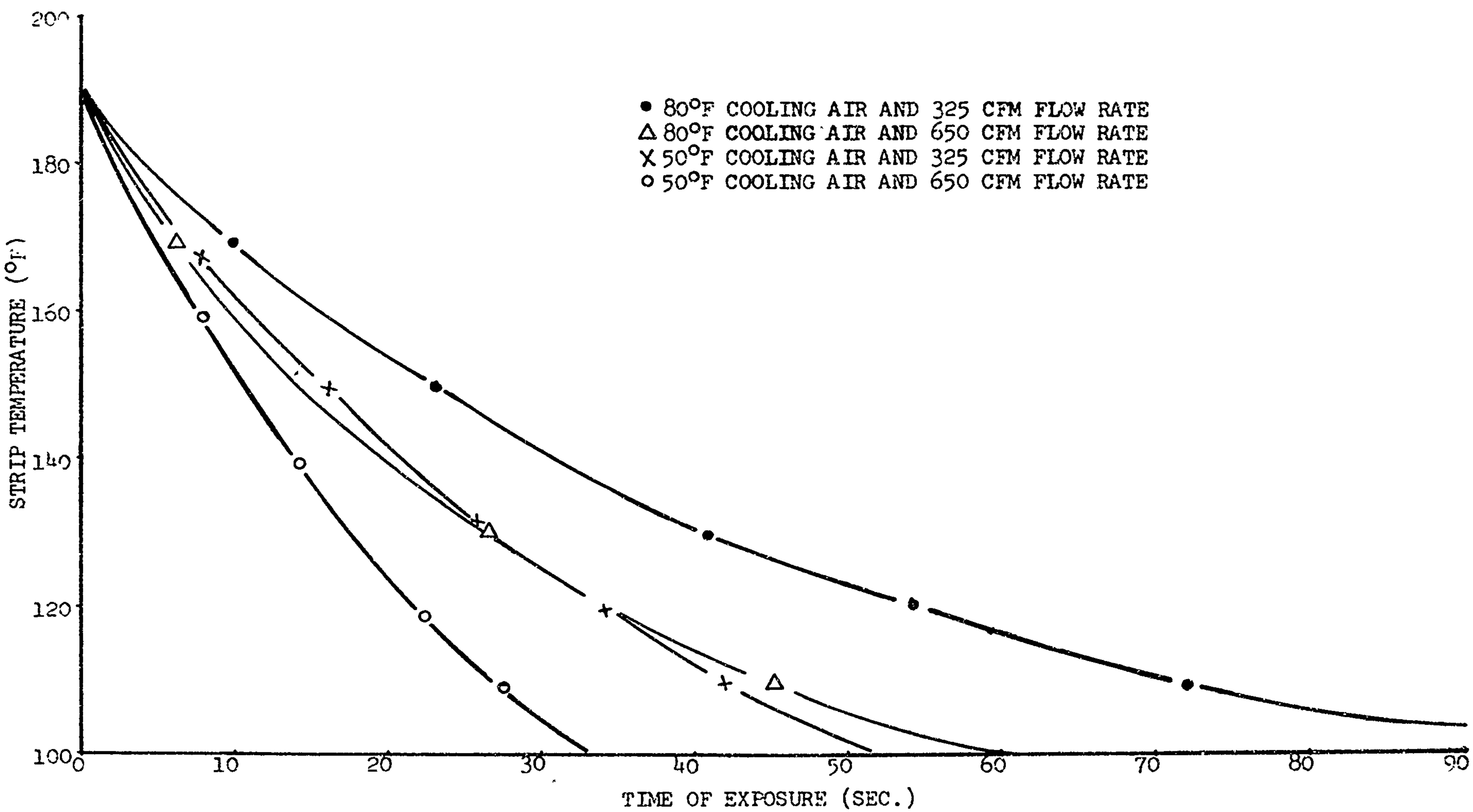


FIGURE 4
COOLING N-5 CARPET ROLL STRIP WITH AIR. FULL SCALE TEST COOLING RATE CURVES

Design Engineering for Next Generation
of a Mechanized Roll Facility

Calculated Length of Plate at 20°F to Cool N-5 Propellant Strip from 150°F to 100°F

I. Cooling Required

Bas : 800 pounds per hour production rate

$\frac{800}{60}$ = 13.3 lbs/min.

Final Roll Speed = 44 feet per minute

(From Fig. 3)

Specific Heat of N-5 Carpet Roll = 0.45 BTU per °F per lb.

(800) X (150 - 100) X (0.45) = 18,000 BTU per hr.

II. Surface Area Required

$$A = \frac{Q}{U \times \Delta T_{LM}}$$

A = Area in ft.^{2}

Q = Heat Transferred per hr. = 18,000 BTU

U* = Heat Transfer Coefficient

ΔT_{LM} = Log Mean Temperature Difference between Propellant Temperature and Cooling Surface

*Estimated at 40 BTU/°F ft.^{2} hr. from Heat Exchange Data (See Note 1.)

$$\Delta T_{LM} = \frac{(150-20) - (100-20)}{\ln \frac{130}{80}} = 103^{\circ}F$$

$$A = \frac{18000}{(40)\ (103)} = 4.38 \text{ ft.}^2$$

III. Length of Strip for 4.38 ft.^{2} Contact Surface

Strip Width (W) = 4 3/4" = 0.396 ft.

$$L = \frac{A}{W} = \frac{4.38}{0.396} = 11.1 \text{ ft.}$$

Note 1:

The heat transfer coefficient (U) was estimated from the following data:

Thermal conductivity of N-5 Propellant = 1.33 BTU/ft. °F hr. (Ref. (1))

N-5 Strip Thickness = 0.105 inches

Estimated Minimum Conductive Area = 25% of Total Area

Then $U_c = \frac{1.33 \times 12 \times 0.25}{0.105} = 38$ BTU/ft.^{2} °F hr.

The Heat Transfer coefficient for contact with air over remainder of area is estimated at 2 BTU/ft.^{2} °F hr. (p15 of ref (2)).

References:

(1) Technical Handbook, MK 43, Mod. 1 Propellant Grain, SAAP, Oct. 1969.

(2) Kreith, Principles of Heat Transfer International Textbook Co. 1958.

Note 2:

The temperature readings for the full scale test were taken at the exit of the final roll bay. In order to correct this reading for the temperature of the strip entering and leaving the cooling section along the conveyor a cooling rate was determined with no air flow. Then the time of exposure corresponding to the distance from the pyrometer to the test point was multiplied by this rate to obtain the correction to be applied to the pyrometer reading.

The log mean temperature difference was calculated from the corrected readings and this value was used to plot the points in Figure 1.

Calculations

I. Cooling Rate With No Air Flow

Length of Propellant Strip = 10 ft.
Temperature Measured at 32 FPM = 190°F.
Temperature Measured at 20 FPM = 180°F.
Time of Exposure at 32 FPM = 18.6 Sec.
Time of Exposure at 20 FPM = 30.0 Sec.

$$\text{Cooling Rate} = \frac{190-180}{30.0-18.6} = \frac{10}{11.4} = 0.877^\circ/\text{Sec.}$$

II. Temperature of Strip Entering Cooling Section

Length of Propellant Strip from Thermometer to Point of Initial Cooling = 8 ft.
Time of Exposure at 32 FPM = 15.0 Sec.
Temperature Loss = 15.0 x 0.877° = 13.2°F.
Temperature of Strip Entering Cooling Section = 190° + 13.2° = 203.2°F.

III. Temperature Correction for Strip at Outlet of Cooling Section

Length of Propellant Strip from Thermometer to End of Cooling Section = 1 ft.
Time of Exposure at 32 FPM = 1.9 Sec.
Temperature Loss = 1.9 x 0.877° = 1.7°F.

IV. Cooling Rate Due to Air Circulating

Temperature of Cooling Air = 77°F.
Initial Strip Temperature = 203.2°F.
Final Temperature Reading = 163°F.
Corrected Final Temperature = 164.7°F.

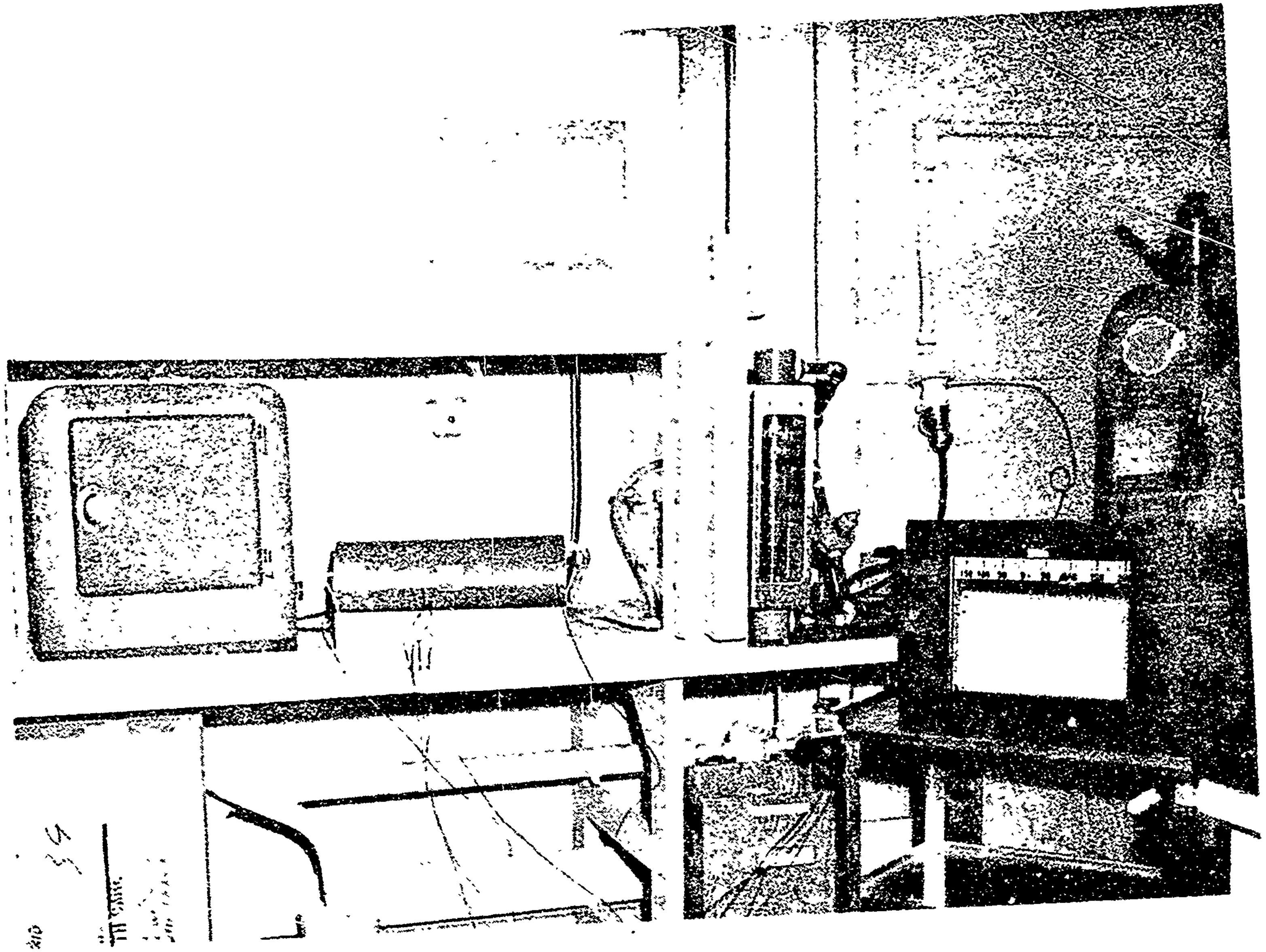
$$\text{Time of Exposure at 32 FPM} = \frac{6 \times 60}{32} = 11.25 \text{ Sec.}$$

$$\text{Rate of Cooling} = \frac{203.2 - 164.7}{11.25} = 3.42^\circ/\text{Sec.}$$

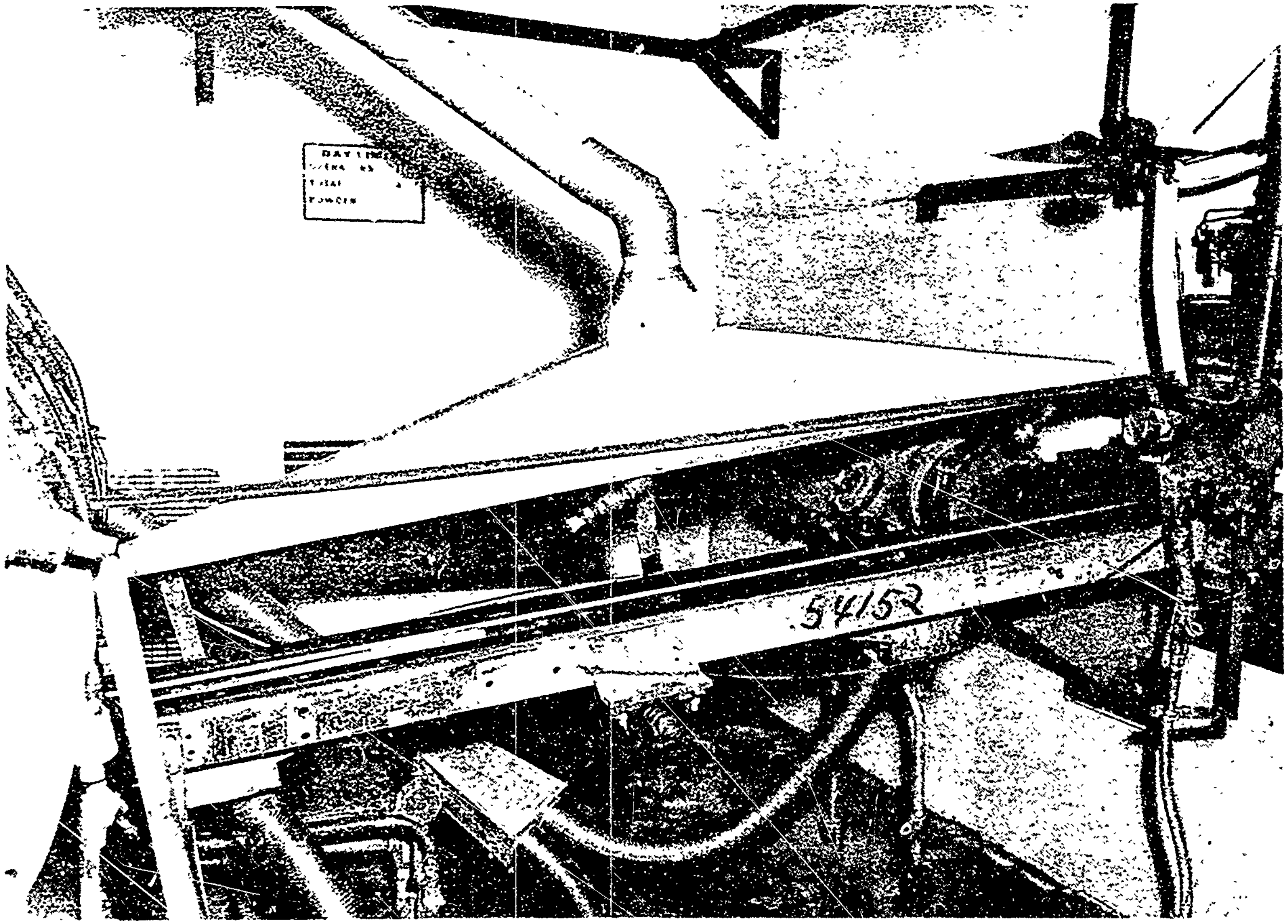
V. Log Mean Temperature Difference

Initial Temperature Difference (ΔT_i) = 203.2 - 77 = 126.2°F.
Final Temperature Difference (ΔT_f) = 164.7 - 77 = 87.7°F.

$$\text{Log Mean Temperature Difference } (\Delta T_{LM}) = \frac{\Delta T_i - \Delta T_f}{\ln\left(\frac{\Delta T_i}{\Delta T_f}\right)} = \frac{126.2 - 87.7}{\ln\left(\frac{126.2}{87.7}\right)} = 105.8^\circ\text{F.}$$



NO. 5. LABORATORY TEST EQUIPMENT USED TO DETERMINE COOLING RATE OF N-5 PROPELLANT WITH INCREASED AIR FLOW



NO. 6. AIR DIFFUSERS INSTALLED ABOVE AND BELOW CONVEYOR
IN FINAL ROLL BAY

J. A. Montgomery SUN 143-33 15 April 1970

Task A-5

The Feasibility of Drying a Pre-roll Sheet with Heated Air

Digest

Objective

This test was conducted to determine the drying characteristics of an N-5 pre-roll sheet in a temperature range from 190°F to 250°F and the effect of passing heated air over the sheet on its residual moisture content. Drying the pre-roll sheet from above 1.3% to 0.5% residual moisture after it leaves the pre-roll would increase the production rate of a Mechanized Roll by a substantial amount.

Summary of Results

From a laboratory test the effect of temperature on the drying rate of a pre-roll sheet was determined by convection heating. The drying of the propellant from 1.3% residual moisture to 0.5% was achieved in four minutes at 250°F. This time will be reduced appreciably if a stream of air is passed over the surface of the sheet. Figure 1 shows the effect of temperature on drying rate.

A full-scale test in which compressed air was used as a heating medium was not successful because of the cooling effect resulting from the expansion of the air.

The residual moisture variation with roll cycle time was used to estimate the effect of a drying operation on the production rate of a Mechanized Roll.

It appears that a 28% increase over the present production rate would result from drying the sheet after it leaves the pre-roll.

Although the effect of drying by forced convection at above 200°F was not demonstrated, the effect of air velocity was estimated by an analogy with heat transfer data. The overall drying rate was estimated at about minus 0.7% moisture per minute at 230°F. This rate is sufficient to warrant further testing in a forced convection dryer.

Conclusion

The drying of a pre-roll sheet in a heated compartment at temperatures between 200°F and 250°F appears feasible. The expected reduction in pre-roll cycle time would be between 23% and 28% of the present roll cycle. The effect of the reduction in rolling time on propellant quality has not been determined.

It is recommended that a forced convection dryer be tested along with a quantitative test on the effect of reduced cycle time on product quality.

Introduction

The production rate of the present Mechanized Roll Facility is limited by the time required to roll the pre-roll sheet. This pre-roll cycle time is governed by the moisture content of the carpet roll. The moisture remaining in the carpet roll should be about 0.5% in order for the MK 43 grain moisture to remain within the normally preferred limits of 0.3% to 0.4%. The moisture control of the product by the present Mechanized Roll facility was improved by the installation of an air purge under the pre-roll mill and a blower system in the pre-roll and final roll bays. The plans for the next generation of the Mechanized Roll include a dwell bay between the pre-roll and final roll bays. The purpose of the dwell bay is to allow the pre-roll sheet time to dry and cool prior to the final roll operation.

The conditioning cycle in the dwell bay will use a stream of air across the surface of the sheet to speed the drying and cooling of the propellant. The purpose of this test was to determine if moisture control could be enhanced by using a short drying cycle prior to the cooling cycle. This task consisted of a laboratory test to determine the drying characteristics of the pre-roll propellant sheet and a full-scale test in a differential roll bay to evaluate the effect of air flow and air temperature on the drying rate. From the results of these tests, the feasibility of using a drying cycle on a continuous basis in the dwell bay of the next generation of the Mechanized Roll would be determined.

Discussion of Results

The laboratory report is included in Appendix A of this report. The results obtained in the laboratory on drying rates of N-5 propellant pre-roll sheet in a convection oven are tabulated in Table I and shown in Figure 1. The data in the laboratory report show that for each of the temperatures used in the test the drying rate approximates a straight line function for the first 0.8% moisture loss. Since the initial moisture content of the laboratory samples averaged 1.3%, this loss represents the range of 1.3% to 0.5% in the moisture content of the samples. Figure 1 of this report makes use of the laboratory results representing the 1.3% to 0.5% moisture range at each test temperature and the straight line relationship to show the effect of temperature from 190°F to 250°F on drying rates. The data shows the drying rate doubles when the temperature is increased from 210°F to 250°F. Although the maximum drying rate demonstrated was only 0.2% per minute at 250°F, this would be increased appreciably by the application of a stream of air across the surface of the sheet. If the sheet were pre-heated to near the drying temperature, as it would be in the pre-roll operation, the time required to dry it to 0.5% residual moisture would be reduced further.

The full-scale test in the differential roll bay was not successful due to the use of compressed air as a drying medium. The air was heated to about 50°F above the desired test temperature in a steam-to-air heat exchanger, but the drying chamber was never above 170°F because the compressed air cooled due to expansion and mixed with the ambient air which passed through the drying unit along the conveyor. An attempt was made to minimize the heat loss in the air line between the heat exchanger and the drying chamber by installing a steam tracer in contact with the air line inside the insulation. To reduce the loss of temperature due to ambient air entering the drying chamber, a steam coil was placed above and below the conveyor inside the chamber. These measures left the air expansion as the major factor causing the low temperature experienced in the drying chamber.

Table II data show the change in moisture experienced by a differential sheet during the last 45 seconds of the roll cycle. The results are plotted in Figure 2. This plot serves as a basis for estimating the decrease in roll time which would result if a dryer were used as part of the rolling process. For drying propellant from 1.3% to 0.5% moisture the reduction in cycle time would be 37 seconds or 28% of the cycle time. Drying the sheet from 1.0% to 0.5% moisture would reduce the cycle time 30 seconds or 23% of the total cycle time. Applying these values to the cycle time used on the Mechanized Roll, the effect would be to reduce the cycle time from one minute and forty seconds (1:40) to approximately one minute and twelve seconds (1:12).

The B Section of Table II shows that very little drying resulted when the air was applied at a temperature of 160°F. In Table III and Figure 3, a comparison of temperature profiles obtained with a radiation pyrometer under different conditions of temperature and air flow around the differential roll is shown. The profiles represent the change in surface temperature of the propellant sheet while it is being rolled. By a comparison of residual moisture under different conditions, some important effects in the drying process can be determined.

The drying process involves the transfer of moisture through two mechanisms in series. The first is the diffusion of moisture from the interior of the propellant sheet to the surface and the second is the removal of moisture from the surface. It is important to know which of these mechanisms controls the overall rate of the drying process.

The diffusion rate through the material varies with the physical characteristics of the material such as porosity, density, and viscosity plus the vapor pressure and molecular activity of the material (moisture) being diffused and the concentration gradient of the moisture from the center to the surface of the sheet.

The primary conditions that would change the rate of diffusion would be a change in sheet thickness, in temperature, and in the concentration gradient. If the diffusion rate were the controlling factor in propellant drying the rate measured in a convection oven would not differ appreciably from the rate on the differential roll at the same temperature. The temperature profile in Figure 3 shows the differential sheet is normally above 200°F during the last 45 seconds of the roll cycle and reaches a temperature above 230°F. A comparison of overall drying rates shows that the propellant sheet was dried eight times as fast on the roll as it was in the convection oven in the same temperature range.

Since the sheet thickness and temperatures were comparable in the convection oven and differential roll drying operations, the only remaining condition affecting the diffusion rate would be the concentration gradient. If the concentration gradient from the center to the surface of the propellant sheet were the controlling factor in the overall drying rate, the rate of drying at any one temperature would decrease rapidly as the material became drier. This was not in accordance with the results obtained in the laboratory in the moisture range from 1.3% to 0.5%. Therefore, the difference in drying rates between the convection oven and the differential roll cannot be explained by conditions affecting the diffusion rate and the diffusion mechanism does not limit the overall drying rate.

If the mass transfer from the propellant surface were the mechanism controlling the overall drying rate during the last part of the rolling cycle, then the air flow rate across the surface of the sheet as well as temperature would change the drying rate. The other factors involved would be vapor pressure of the liquid, film thickness, exposed surface area and relative humidity of the air. Again a comparison of these factors between the convection oven and the differential roll at the same temperature shows that air velocity is one difference in the two operations and the shearing effect in the roll bite is another. The exposed surface would be greater in the convection oven since one side of the sheet is in contact with the roll and would not be exposed during the rolling operation.

A test was made to show the effect of increased air flow on the differential roll. If mass transfer by forced convection were the controlling mechanism, the increased air flow would increase the drying rate at any one temperature. A compressed air distributor was placed under the roll and air flow around the roll was increased during the last two minutes of the roll cycle. The air was heated to 205°F to reduce the cooling effect of the air on the propellant. Figure 3 shows the temperature profile obtained. The moisture was reduced to 0.48% in one run and 0.58% in the other at an average temperature 20°F below the normal propellant surface temperature. A temperature profile in the same range as the test sheets was obtained with low roll temperatures without the air flow, but the residual moisture remained above 1.2%. This profile is shown in Figure 4. Thus at comparable temperatures, the increased air flow resulted in a difference of 0.75% in the residual moisture. This would be the expected effect if the moisture removal from the surface by forced convection is the controlling mechanism in the overall drying rate. Table III shows the test data.

Since the removal of moisture by forced convection has been established as the controlling mechanism, an estimate of the effect of air velocity on drying rate can be made from heat transfer data by the Reynolds analogy. According to the Reynolds analogy, the ratio of mass transfer rates by forced convection at two different air velocities is equal to the ratio of heat transfer rates at the corresponding air velocities.

The cooling rate test of Task A-4 of this project provides heat transfer data at air velocities from 0 to 25 CFM readings on the flow meter. Figure 1 of the Task A-4 report is a plot of a series of straight lines showing cooling rates at various air velocities. The laboratory data portion of this figure is reproduced with the zero velocity line added in Figure 5 of this report. The data for Figure 5 is in the laboratory report on cooling N-5 carpet roll strip found in the Appendix. From Figure 5 the ratio of cooling rates at different air velocities can be read directly and is in direct proportion to the heat transfer ratio for these velocities. These ratios were applied to the drying rates obtained in the laboratory and the times required to dry a propellant sheet at 230°F and at 250°F under various air velocities were derived and tabulated in Table IV. These values show the 25 CFM air velocity would increase the drying rate by about four times over that obtained in a convection oven. This estimate of the effect of air velocity on drying rate is conservative for three reasons:

(1) The temperature readings for the cooling rate data were those of the propellant sheet while the drying rate data shows the oven temperature but not the propellant temperature.

(2) In the drying rate tests, no time correction was made for the warm-up period after the sample was placed in the oven, although this would be partially compensated for by the cool-down time after the sample was removed from the oven.

(3) The condition of the propellant surface affects air turbulence and one of the differential sheet surfaces is rough when compared to the carpet roll strip which was used for the cooling rate test.

When the above estimate is used as a basis of comparison of drying rates on a differential roll with those in a forced convection dryer, it is found that the drying rate in a dryer will be about one-half that on a differential roll. It appears likely the estimated dryer rate could be increased by some design features such as air flow control that have been shown to increase the effect of forced convection in air dryers. Even without an improvement of this nature, a drying cycle approximately equal to the roll cycle appears possible at temperatures above 230°F in a forced convection dryer.

If a dryer is used to control the moisture in a pre-roll sheet, the cycle time may be reduced to the point where consolidation or "colloiding" of the sheet will become the factor limiting the Mechanized Roll capacity. There have been no quantitative tests to determine the effect of a reduced cycle time on sheet quality. Such a test would be necessary to prove the feasibility of using a drying cycle to reduce the pre-roll cycle time. A preliminary test was made by removing pre-roll sheets after one minute on the roll and they appeared to be well colloided. The possibility of increasing the sheet thickness should also be tested along with the reduced cycle time.

Conclusions and Recommendations

A) Conclusions

1) The temperature of the pre-roll sheet has an appreciable effect on the drying rate in the range from 190°F to 250°F.

2) The characteristics of the N-5 pre-roll sheet are such that a reduction in residual moisture from 1.3% to 0.5% appears feasible in a forced convection dryer following the pre-roll at temperatures between 200°F and 250°F.

3) A drying unit capable of drying the N-5 pre-roll sheet from 1.3% to 0.5% residual moisture content would increase the production rate of a Mechanized Roll Facility by 28% provided a reduced cycle would not reduce the quality of the sheet due to insufficient colloiding.

B) Recommendations

It is recommended that a forced convection dryer be procured and tested along with a quantitative test on the effect of a reduced pre-roll cycle on carpet roll quality. The possibility of an increase in sheet thickness should be investigated if the dryer proves feasible.

The design of the next generation of the Mechanized Roll will not be affected at this time since the present configuration includes a dwell bay which will provide room for the drying operation.

TABLE I

Design Engineering for Next Generation of a Mechanized Roll Facility

Effect of Temperature on the Drying Rate of an N-5 Pre-roll Sheet in a Convection Oven

Average Moisture Content of Samples = 1.3%

Average Moisture Content of Dried Product = 0.5%

Test No.	Oven Temperature (°F)	Time to Dry to 0.5% (Min.)	Drying Rate (%/Min.)
1	190	9.7	0.082
2	210	7.4	0.11
3	230	5.0	0.16
4	250	4.0	0.20

TABLE II

Design Engineering for Next Generation
of Mechanized Roll Facility

The Feasibility of Drying a
Pre-roll Sheet with Heated Air

DATA SUMMARY

(Drying Test in Building 7807-3)

Operating Conditions:

Bare Roll Temperatures (Heated with Steam)

Front Roll	210°F
Back Roll	220°F
Roll Speed	84.2 FPM (Front Roll)
Charge Weight	4.75 pounds
Sheet Thickness	0.047 inches
Rework	5%

A. Moisture Content of an N-5 Differential Sheet at Different Cycle Times

Average Moisture Content of N-5 Paste = 9.1%

Run No.	Cycle Time (Minutes)	Residual Moisture in Differential Sheet (%)
1	1.50	1.48
2	1.75	0.95
3	2.00	0.74
4	2.17	0.55

TABLE II (Continued)

B. Loss of Moisture Due to Air Drying

Average Moisture Content of N-5 Paste = 8.6%

Run No.	Cycle Time (Minutes)	Time in Dryer (Minutes)	Dryer Temp. (°F)	Air Flow (SCFM)	Residual Moisture in Diff. Sheet (%)
1	1.50	1	160	56	1.20
2	1.50	2	__*	50	1.38
3	1.50	4	__*	50	1.65
4	1.75	2	165	56	0.98
5	1.75	2	160	56	1.21

*These tests were made without the compartment and steam coils installed over the conveyor.

TABLE III

Design Engineering for the Next Generation of a Mechanized Roll Facility

Temperature Profiles of
N-5 Propellant on a Differential Roll

Operating Conditions:

Bare Roll Temperatures (Heated with Steam)

Front Roll	205°F
Back Roll	210°F
Roll Speed	84.2 FPM (Front Roll)
Charge Weight	4 3/4 pounds
Sheet Thickness	0.047 inches
Rework	5%

Average Paste Moisture 8.2%

Sheet Temperature vs. Time on Differential Roll

A. No Air Flow

Time (Sec)	Run 1 Temperature (°F)	Run 2 Temperature (°F)	Run 3 Temperature (°F)
10	162	162	162
20	180	176	176
30	182	182	180
40	188	188	186
50	196	198	194
60	204	204	201
70	208	210	206
80	214	218	211
90	218	220	215
100	224	224	219
110	226	228	222
120	230	230	224
128	232	232	228
Residual Moisture (%)	0.54	0.55	0.53

TABLE III (Continued)

B. With 25 CFM Air Flow

Time (Sec)	Run 1 Temperature (°F)	Run 2 Temperature (°F)
10	152	150
20	164	161
30	168	162
40	176	167
50	182	175
60	188	183
70	194	188
80	198	192
90	200	197
100	204	200
110	206	203
120	208	205
128	210	208
Residual Moisture (%)	0.58	0.48

TABLE III (Continued)

C. With a Low Roll Temperature

Bare R.ll Temperatures:

Front Roll 175°F
Back Roll 200°F

Time (Sec)	Run 1 Temperature (°F)	Run 2 Temperature (°F)
10	158	160
20	168	167
30	168	171
40	171	175
50	177	175
60	178	176
70	180	178
80	183	182
90	186	187
100	192	192
110	196	197
120	200	202
128	203	203
Residual Moisture (%)	1.22	1.28

TABLE IV

Design Engineering for the Next Generation of a Mechanized Roll Facility

Effect of Air Velocity on the Drying Rate of an N-5 Pre-roll Sheet at Two Temperatures

(Derived from Laboratory Data on Cooling Rates by the Reynolds Analogy)

Basis: Drying N-5 Propellant from 1.3% to 0.5% Residual Moisture

A. Drying Rate at 230°F

Air Flow Rate (CFM)	Time to Dry (Minutes)	Drying Rate %/Minute
0	5.0	0.16
5	3.3	0.24
15	1.9	0.42
25	1.2	0.66

B. Drying Rate at 250°F

Air Flow Rate (CFM)	Time to Dry (Minutes)	Drying Rate %/Minute
0	4.0	0.20
5	2.7	0.30
15	1.5	0.53
25	1.0	0.80

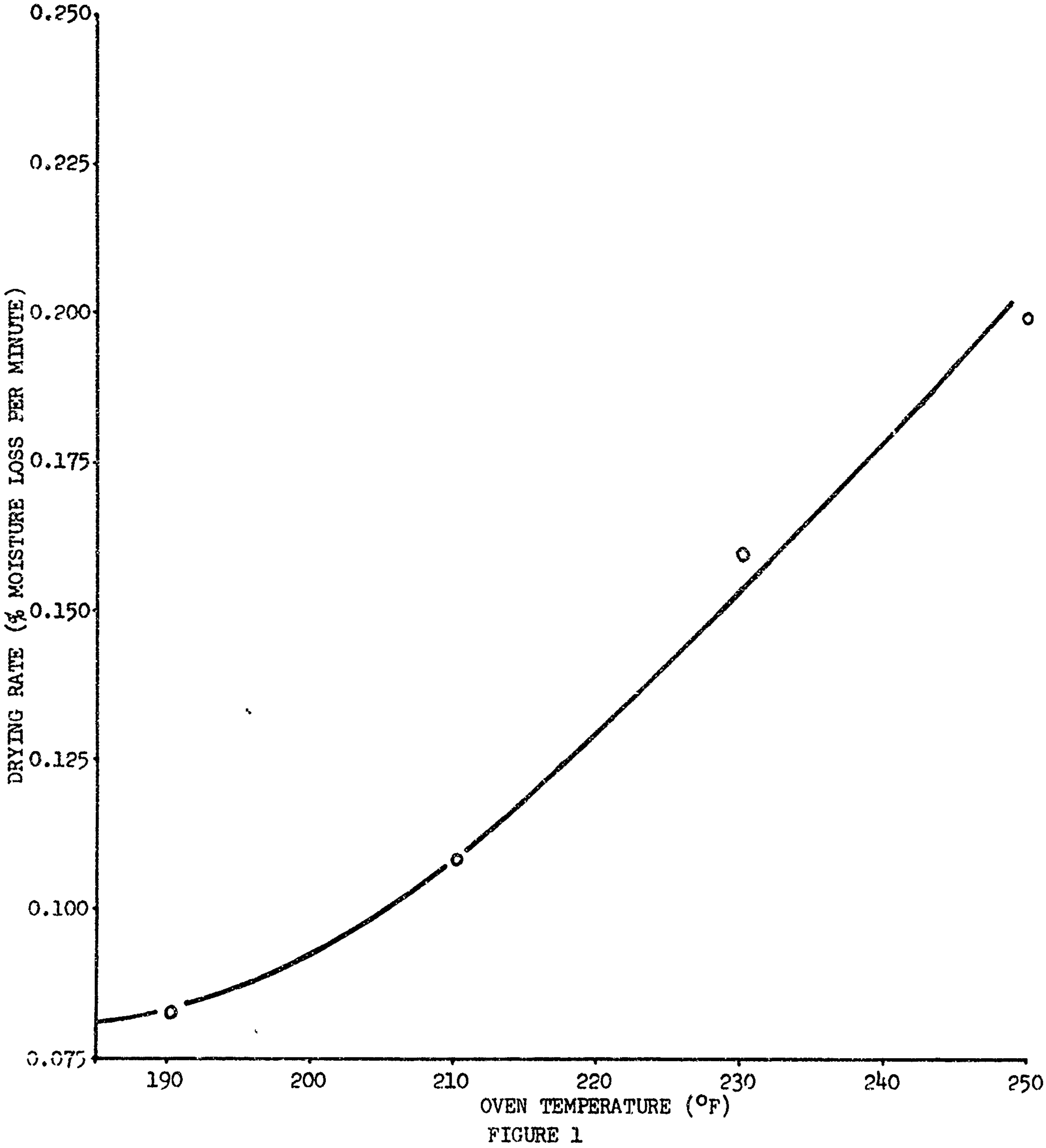


FIGURE 1

DRYING RATE CURVE FOR N-5 PROPELLANT PRE-ROLL SHEET IN A CONVECTION OVEN FOR 1.3% to 0.5% MOISTURE RANGE

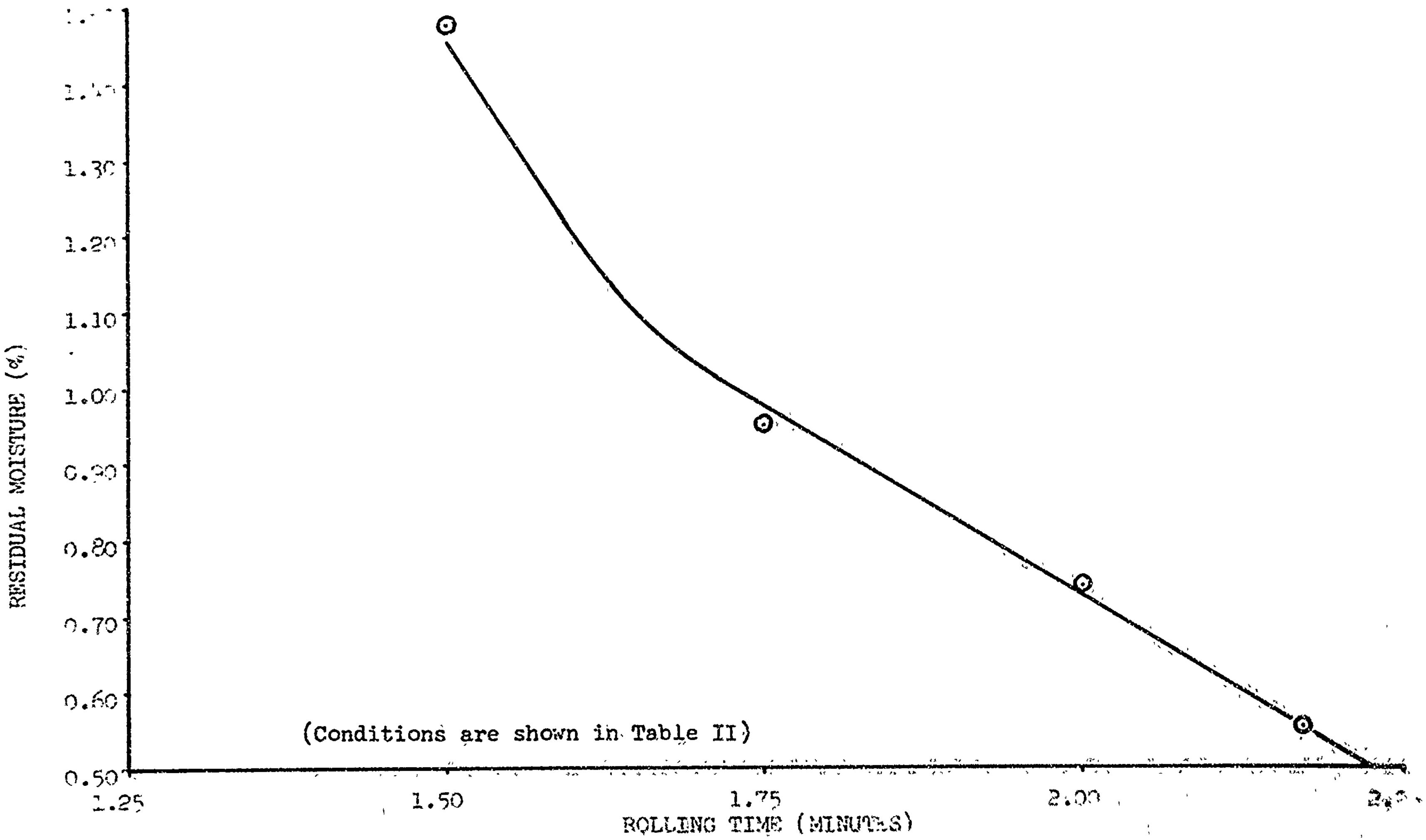


FIGURE 2
MOISTURE CONTENT VS ROLLING TIME OF N-5 DIFFERENTIAL SHEET

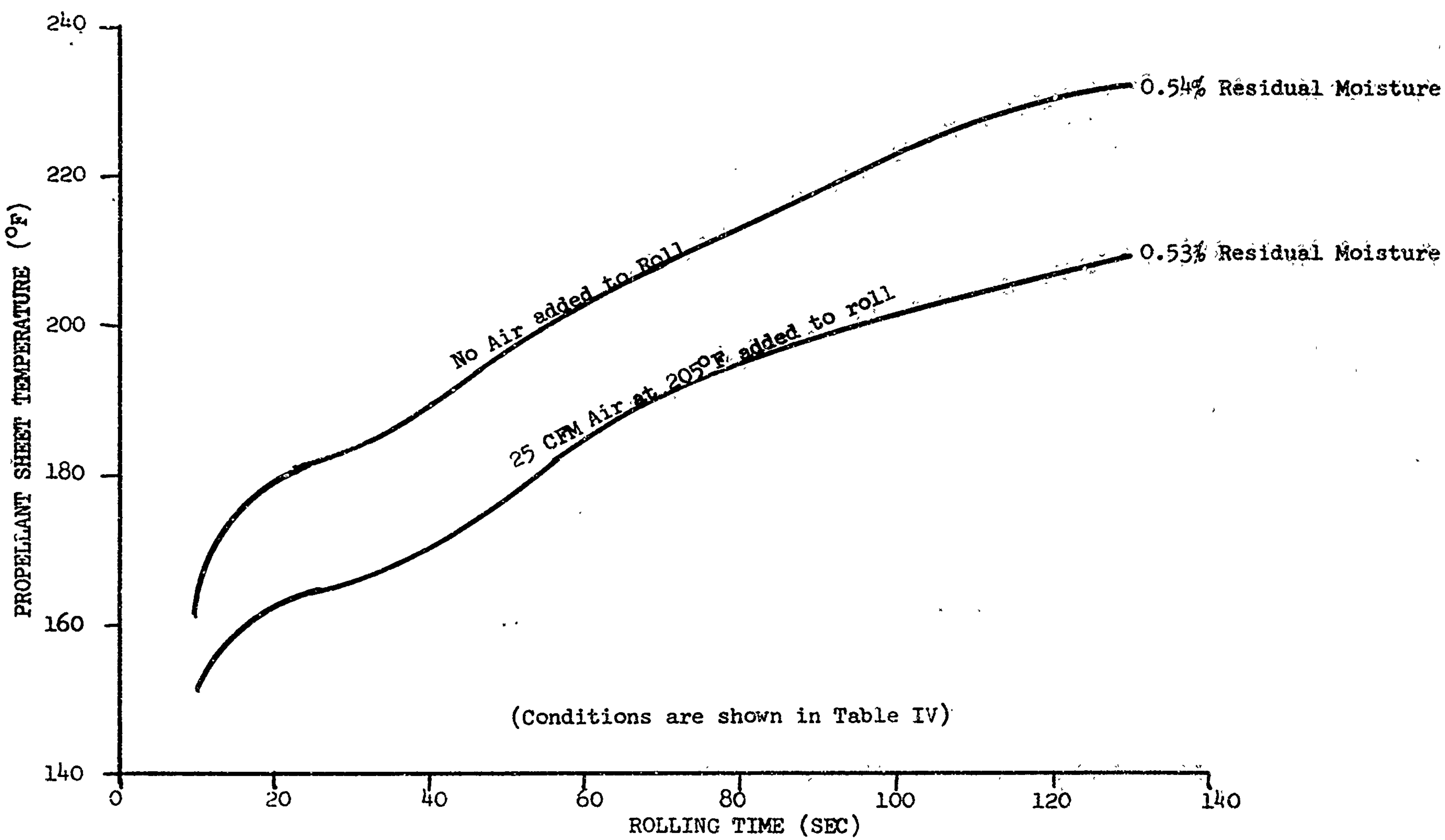


FIGURE 3

EFFECT OF INCREASED AIR FLOW ON TEMPERATURE PROFILE OF N-5 DIFFERENTIAL SHEET

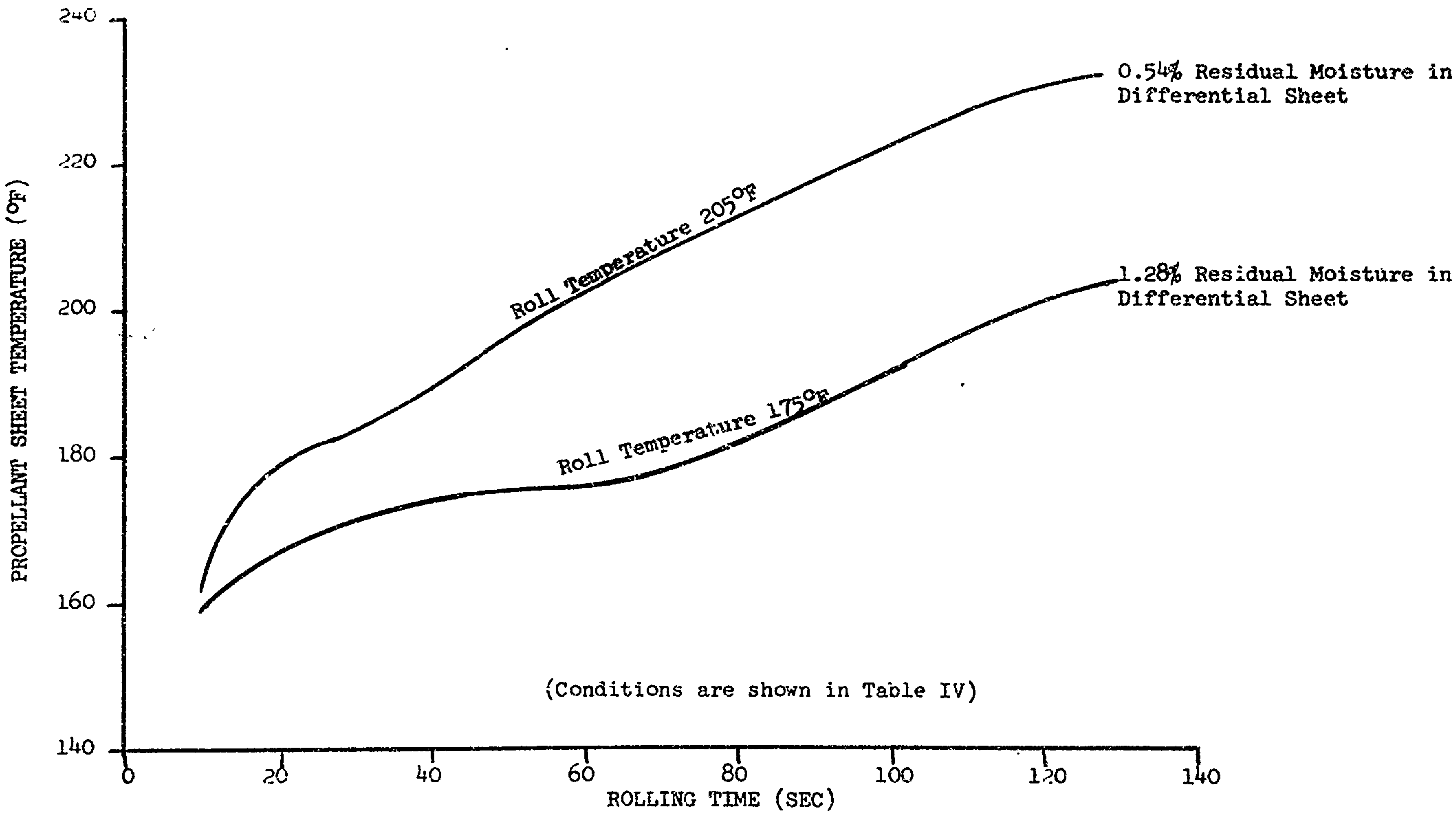


FIGURE 4

EFFECT OF LOW ROLL TEMPERATURE ON TEMPERATURE PROFILE OF A DIFFERENTIAL SHEET

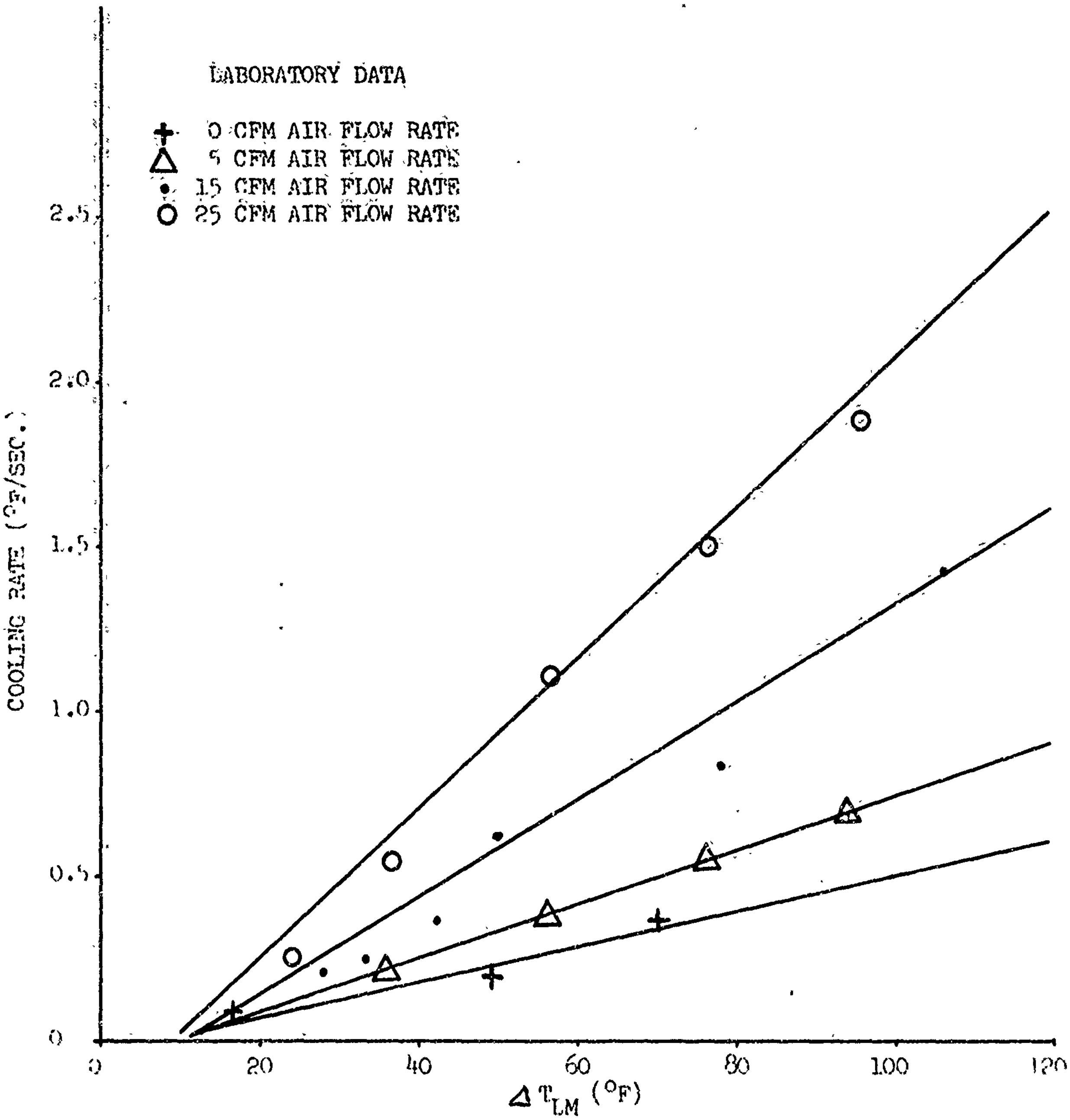
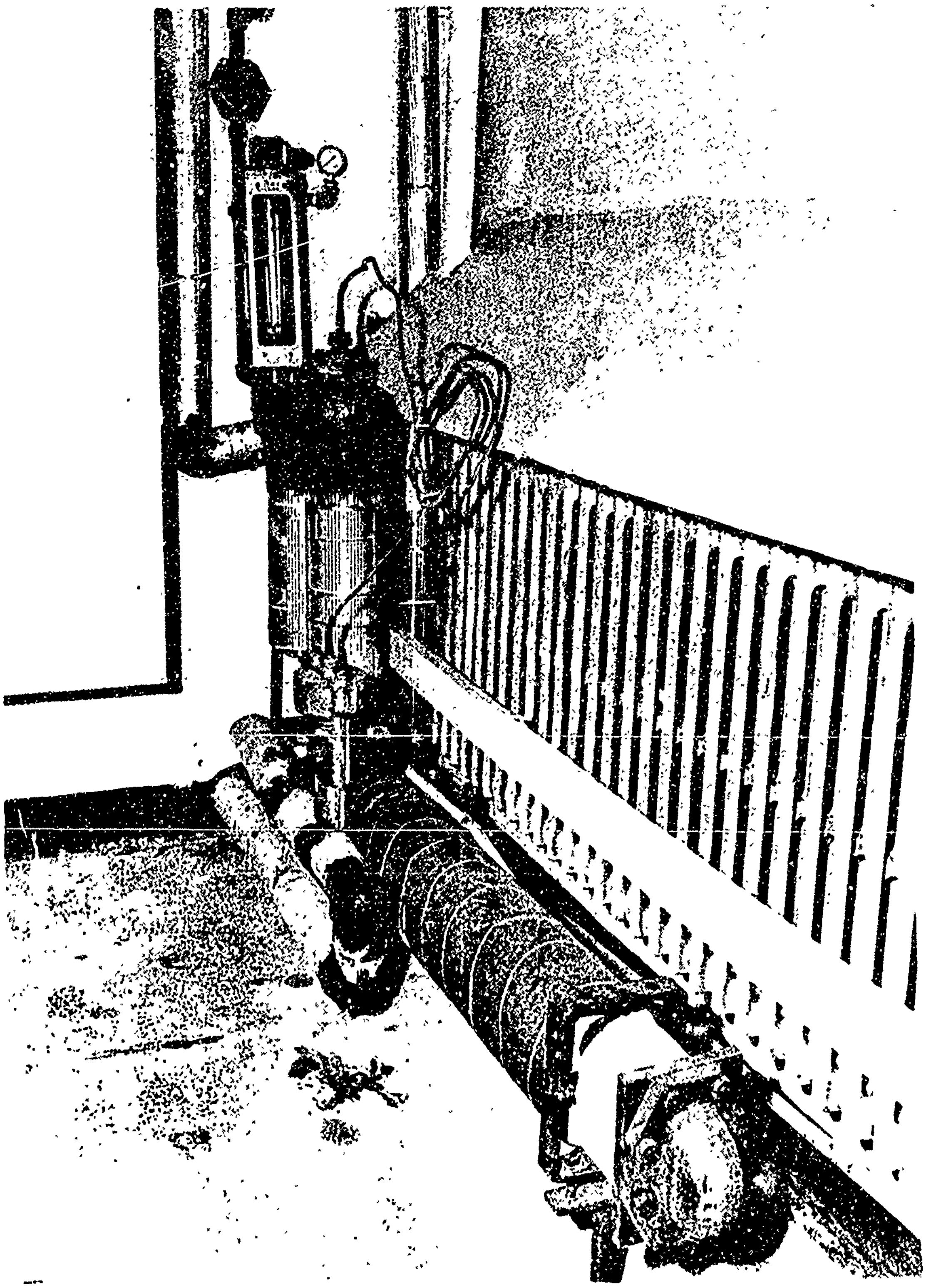


FIGURE 5
COOLING N-5 CARPET ROLL STRIP WITH AIR COOLING RATE vs TEMPERATURE DIFFERENCE



NO. 7. STEAM TO AIR HEAT EXCHANGER USED TO HEAT AIR FOR DRYING N-5 DIFFERENTIAL SHEET

Shep Lampkin SUN 143-33 15 April 1970

Task A-6

Testing of Improved Materials for Conveyor Belts

Objective:

The conveyor belts used in the present mechanized roll are not fire resistant and absorb exudate from the propellant which makes them even less fire resistant. This task is to obtain better materials for conveyor belts.

Discussion:

Manufacturers of conveyor belting were contacted for availability of high temperature resistant non-metallic material. At the present time "off-the-shelf" materials have a maximum temperature range of 350° F. Compatibility with nitroglycerin was also an item of the product research. Manufacturers' samples that appeared likely were obtained and subjected to laboratory analysis for propellant compatibility. Those samples which were compatible were then tested for nitroglycerin absorption and heat resistance. Three samples with low absorption rates and in the higher heat resistance range appeared to be acceptable and belts of each material were purchased for full scale testing.

The materials selected were:

1. 1/8" thick two ply cotton fabric with 1/32" thick cover top and bottom of Uniroyal Butyl compound #5950.
2. 1/8" thick, two ply, cotton fabric, 1/32" thick cover top and bottom of Hypalon.
3. 1/8" thick, Durapol Belting, two ply Polyester Fabric with Hycar top.

Conclusion:

The Durapol belting was tested for 25 days on a 3-8-7 shift basis when it had to be replaced. The fibers absorbed exudate and stretched to the point that buckling at the center of the belt occurred. The Uniroyal belt was installed and has run 30 days at this writing and appears to be in the original condition. The Hypalon belt will be evaluated at a later date.

J. A. Montgomery SUN 143-33 15 April 1970

Task A-7

Investigation of a Method for Increasing the Capacity of the Final Roll Mill

Digest

Objective

The purpose of this test was to determine if the capacity of the final roll mill could be increased without increasing the roll speed. The feasibility of removing two carpet roll strips in parallel and a method for the elimination of side strips were tested. The elimination of side strips on the final roll would simplify the operation and prevent propellant waste.

Summary of Results

A preliminary t of propellant which had passed through the final roll bite only once showed that this was sufficient rolling to produce acceptable carpet rolls. Considering this fact, the side plates were spaced exactly two strip widths apart and the contour of the side plates was changed so that the tips extended into the roll bite. The initial test with two carpet roll strips in parallel and no side strips produced acceptable carpet rolls but a fringe remained on the outside edge of the strips due to a thin extrusion of propellant between the side plates and the rolls.

A second test was made after the side plates had been coated with teflon so less clearance could be maintained between the side plates and the rolls. This eliminated the fringe on the top edge of the strip, but it remained on the bottom because the contour of the plates did not permit a close fit in the approach section. However the test demonstrated that a close fitting side plate would produce a smooth edge on the propellant strip.

Tensile strength, hardness, and strand burning rates showed the quality of the carpet rolls was comparable to the product of the normal one-strip process.

Conclusion

Based on the results of this test the final roll capacity can be doubled without increasing the roll speed by taking two strips off the roll in parallel. Operation of the final roll without side strips is also feasible. The elimination of a thin fringe of propellant along the edge of the propellant strip requires a close fit with less than a 0.005-inch clearance between the side plate and the roll. This method of increasing the final roll capacity and operating the final roll without side strips being plowed back is recommended if the production rate of the mechanized roll is increased to the point where the final roll speed becomes critical.

J. A. Montgomery SUN 143-33 15 April 1970

Investigation of a Method for Increasing the Capacity of the Final Roll Mill

Introduction

Since the end of 1967 the production rate for the present mechanized roll has been increased from 525 pounds per operating hour to above 660 pounds. The final roll speed has been increased from 29 feet per minute to 37 feet per minute. With the process improvements expected with the next generation of the mechanized roll, the production rate may be increased to the point where the final roll speed will contribute to conditions conducive to roll fires. In this case the removal of two strips of propellant in parallel could be used to increase the capacity of the final roll mill without increasing the roll speed.

An additional advantage in the operation of the final roll mill would be realized if the side strips could be eliminated. Under present operating conditions the side strips are plowed back into the roll bite. Poor adhesion of the strips to the roll and breaks in the side strips result in the propellant falling off the roll. This requires an operator to enter the roll bay to feed the strip back into the roll bite. Any material which is torn off as excess is wasted. The elimination of the side strips by changing the spacing of the side plates and redesigning the side plates was considered possible and desirable.

This task was undertaken to determine the feasibility of removing two (2) strips from the final roll mill and to determine if the side strips could be eliminated.

Discussion of Results

A preliminary test was made to determine if the physical properties and burning rate of the propellant were acceptable after it had passed through the final roll bite only once. This was accomplished by taking samples of the carpet roll strip when the side strips were removed along with it so that no propellant was returned to the roll bite. Three (3) samples taken in this manner were tested for tensile strength, strand burning rates and hardness. The results are shown in Table I. A comparison was made with samples taken during normal operation. Due to the sample size the samples were composited for the tensile testing.

A calculation was made to compare the amount of rolling the propellant receives on the final roll by the two (2) methods. The propellant passes through the roll bite an average of 1.95 times during normal operation so the amount of rolling is reduced by about 50% by a single pass through the roll bite.

When it appeared the propellant would remain acceptable after a single pass through the final roll bite, a test was designed to determine the feasibility of removing two carpet roll strips in parallel. By using a new design for the side plates, the possibility of eliminating the side strips could be investigated at the same time.

The feeding, rolling, slitting, and conveying requirements were met on the initial test run. Two (2) carpet roll strips were removed in parallel and wound into carpet rolls. However, a small fringe of propellant was left on the outside edge of the strips due to the extrusion of propellant at the tips of the side plates as it passed through the roll bite. This fringe material was up to one-half inch in width and from 8 to 15 mils thick. The clearance between the rolls and side plates was reduced to about 10 mils, but the results were the same as before. This fringe material is shown in photo No. 1.

In the second test the side plates were teflon coated so the clearance between the rolls and the side plates could be reduced to a minimum without the danger of metal to metal contact. In this test it was found that when the clearance at the tips of the side plates was adjusted, the contour of the plates left about 1/8" clearance at the surface of the bottom roll about six inches from the roll bite. This excess clearance in the approach to the roll bite permitted the propellant an entrance under the tip of the side plate that produced the fringe on one side of the strip, but it was eliminated from the top edge of the propellant strip. It was noted that the tips of the side plates had been bent sometime after the teflon coating had been applied and the machine shop had to realign the tips before the test. From the results obtained in the second test, it appears that the fringe disappears when the clearance is less than five mils between side plate and roll and when this clearance does not increase along the approach to the roll bite. This was the condition along the top side of the strip where no fringe was produced. Photos No. 2 & 3 show the amount of fringe produced on the strip during the second test on the final roll.

Conclusions and Recommendations

A. Conclusions

The following facts were established by this test:

1. The removal of two strips in parallel is feasible for N-5 carpet roll production and presents no problems in the operation of the final roll mill.

2. The operation of the final roll mill without side strips is feasible when two strips are removed in parallel. The amount of rolling the propellant receives on the final roll is reduced by about 50% when side strips are eliminated.
3. A clearance of less than 0.005 inches between the side plates and rolls is necessary to prevent the formation of a fringe on the edge of the strip when the final roll is operated without side strips being plowed back into the roll bite.

B. Recommendations

It is recommended that the use of a two-strip method be considered for the operation of the final roll mill if the roll speed becomes a problem due to increased production rates. The use of the redesigned side plates to eliminate the side strips is also recommended when the two-strip operation is in effect. The possibility of a two-strip operation should be considered in the design and arrangement of conveying, cooling, and winding equipment following the final roll mill in future Mechanized Roll Facilities.

TABLE I

Design Engineering for Next Generation
of Mechanized Roll Facility

Effect of Reducing Final Rolling to a Single Pass through the Roll Bite on Propellant Quality

A. Tensile Strength (on Scott Tester)

	Crosswise (lb/in^2)	Lengthwise (lb/in^2)	Elongation (%)
Regular Mechanized Roll Production	305.2	401.9	56
Single Pass Sample	325.4	386.1	55

B. Strand Burning Rates*

	1100 psia	1350 psia
Regular Mechanized Roll (in/sec)	0.451	0.353
Single Pass Samples (in/sec)		
1	0.440	0.353
2	0.443	0.355
3	0.441	0.351

C. Hardness**

	Durometer D	Creep in 15 sec.
Regular Mechanized Roll Production	40	28
Single Pass Sample	35	22

* Burned at 70°F under oil
** Durometer D, Rex Gauge Co. Instrument

Calculations

1. No. of Times Propellant Passes through Roll Bite on Final Roll Mill

   a. Circumference of Roll (18 in. dia.)
      18 = 56.55 inches

   b. Weight of Propellant on Roll

      (1) Strip 11" wide and 0.105" thick on 3/4 of circumference
          (Propellant Density = 0.0553 lbs/in^3)
          3/4 x 56.55 x 11 x 0.105 x 0.0553 = 2.709 lbs.

      (2) Strip (11"-4 5/8") and 0.105" thick on 1/4 of circumference
          1/4 x 56.55 x 6 3/8 x 0.105 x 0.0553 = 0.256 lbs.

      (3) Total Weight of Propellant on Roll
          2.709 + 0.256 = 2.965 lbs.

   c. Weight of Feed for Each Revolution of the Final Roll

      (1) Production Rate
          660 lbs. per hour production rate
          $\frac{660}{60}$ = 11 lbs. per minute

      (2) Weight of Propellant per foot of carpet roll strip
          (4 5/8 x 0.105 x 12) (0.0553) = 0.3223 lbs/ft

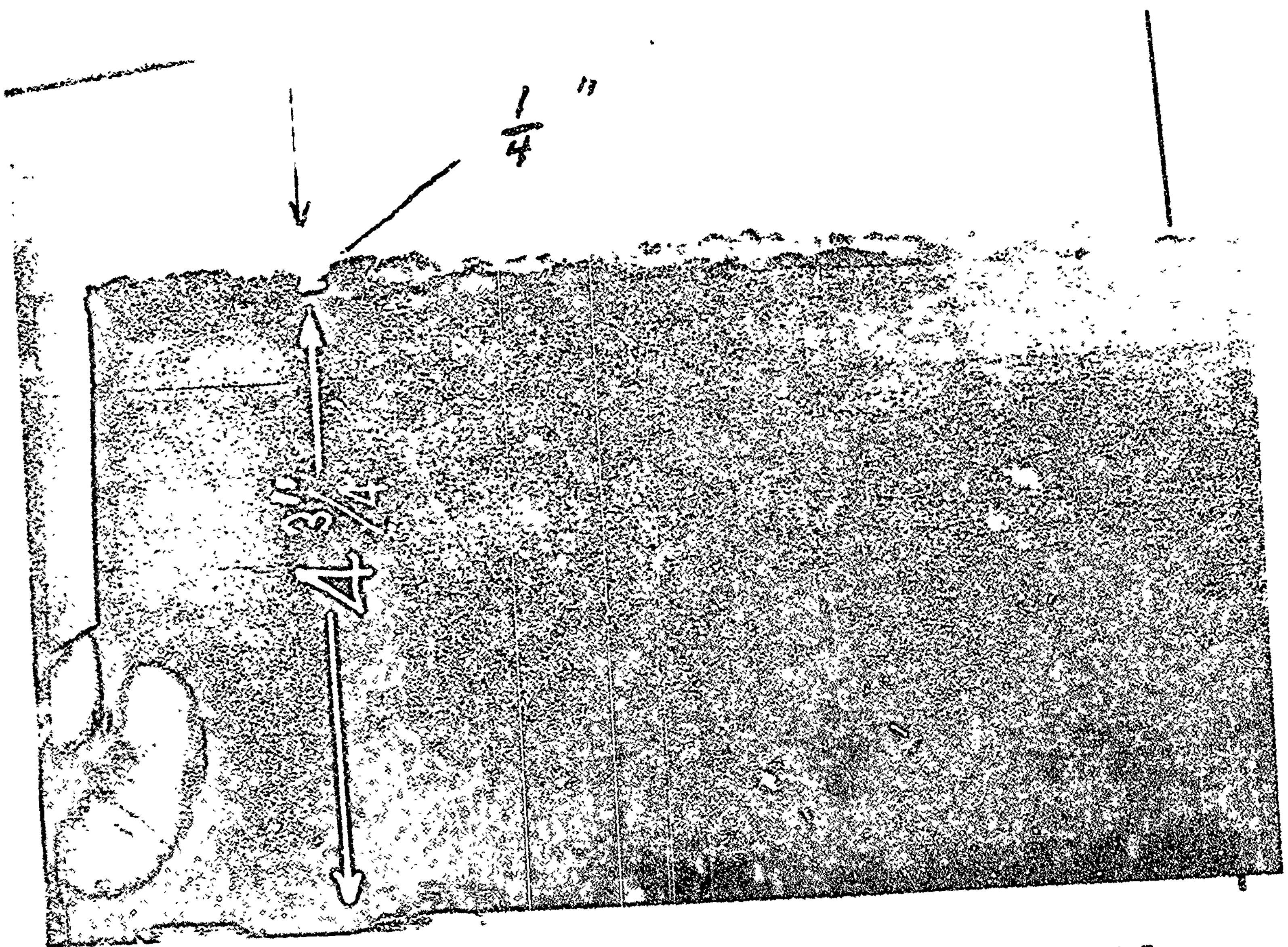
      (3) Final Roll Speed (RPM)
          $\frac{11}{0.3223}$ = 34.12 feet/min

          $\frac{34.12 \times 12}{56.55}$ = 7.24 RPM

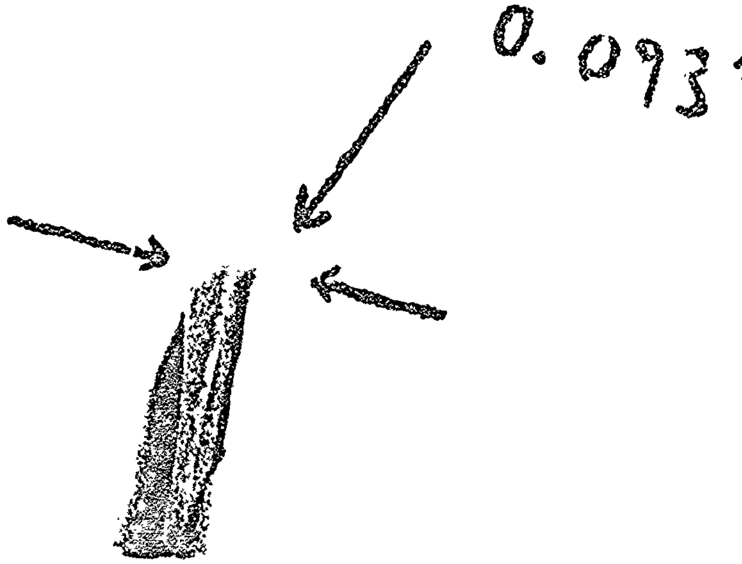
      (4) Product Removed and fed per Revolution of the Final Roll
          $\frac{11}{7.24}$ = 1.519 lbs. propellant

   d. Average Number of Times Through the Roll Bite

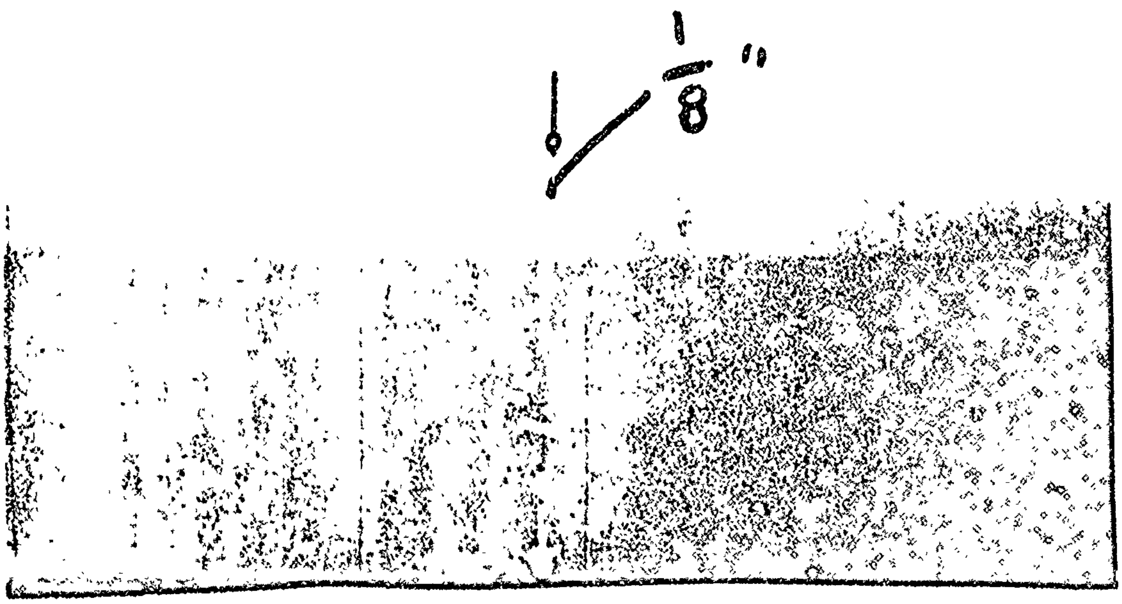
      $\frac{2.965}{1.519}$ = 1.95 is number of times through the roll bite



NO. 1. CARPET ROLL STRIP SHOWING FRINGE PRODUCED IN RUN NO. 1 OF TASK A-7



NO. 2. EDGEWISE VIEW OF A CARPET ROLL STRIP SHOWING FRINGE PRODUCED IN RUN NO. 2 OF TASK A-7



NO. 3. ENLARGED EDGE OF CARPET ROLL STRIP SHOWING FRINGE PRODUCED IN RUN NO. 2 OF TASK A-7

Task B-1

Design of Conveyor Systems

Objective:

To design a system of conveyors to transport the propellant in its various physical states from one process stage to another. The conveyance of material to be automatic and interlocked to the various processing equipment and fire protection system to eliminate manual operation requirements. The systems are to be designed of nonsparking material, powered by explosion-proof drives, and have belts of a product compatible material. The design shall minimize the accumulation of product and shall be of open design to permit ready cleaning and inspection. All bolts and nuts shall be safety wired to prohibit inclusion in the product.

Drawings:

The following drawings were prepared to meet the above objective.

SAAP 7672	Receiving Bay Conveyor Assembly
SAAP 7720	Weigh Room Conveyor Assembly
SAAP 7737	Heating Bay Conveyor Assembly
SAAP 7675	Pre-Roll Conveyor Assembly
SAAP 7718	Dwell Bay Conveyor Assembly
SAAP 7690	Final Roll Conveyor Assembly
SAAP 7782	Final Roll Take-off Conveyor Assem
SAAP 7715	Cooling Bay Conveyor Assembly

Task B-2

Design of Fire Doors

Objective:

To design pass through doors for the fire shields to permit the passing of the product from one process stage to the next and prohibit the propagation of fire from one room to another. The doors shall be constructed of nonsparking material, pneumatically operated, and interlocked with the conveying and fire protection systems. Nonmetallic seals on the doors shall be provided such that no metal to metal contact will occur when the door is closed. Seals shall be designed in such a manner as to prohibit the accumulation of product. Opening of the doors shall be in the direction of material flow.

Drawings:

The following drawings were prepared to meet the above objective.

SAAP 7626	Weigh Room Fire Door Assembly
SAAP 7665	Heat Room Fire Door Assembly
SAAP 7662	Pre-Roll Bay Fire Door & Changing Hopper Assembly
SAAP 7666	Dwell and Final Roll Bay Fire Door Assembly
SAAP 7693	Guillotine Door Assembly

Task B-3

Criteria for Calenders

Objective:

To prepare the criteria for the calenders to convert the propellant paste to colliοded material, utilizing the latest "state of the art" in equipment, and designing for the optimum in production capacity.

Specification:

<u>Four Roll Inclined Z Calender</u>

Description of Material to be Rolled:

The material to be collided is an explosive nitrocotton, nitroglycerin mixture called paste. This material is best described as damp saw dust and has a density of 20 lb/cu.ft.

Description of Function Calender is to Perform:

A batch of 25 lbs. of paste is delivered to the top of the 4 roll calender. The batch will be accepted at the top of the 4 roll calender, into a stainless steel hopper with side guides where the material will band the #2 roll, because of its higher speed than #1 and will do so for a predetermined time, approximately 1½ minutes. While the material is banding on the #2 roll, there will also be a bank between #2 and #3 rolls so there will be two (2) working banks during this initial period.

At the end of the predetermined time cycle, a scraper will be engaged at approximately the two o'clock position of the #2 roll, scraping the material from this roll in sheet form and feeding it down into the bank to be formed between rolls #3 and #4. Here the sheet will band to #4 roll, because of its temperature and higher speed, and will be worked between rolls #3 and #4 for approximately one minute. At this time, the sheet will be cut and scraped off onto a conveyor that will carry the sheet away with the next batch following on through and drop into the position vacated.

General Operation Conditions:

The operating speeds on the calender will be approximately 85 fpm on rolls #1 and #3, and approximately 120 fpm on rolls #2 and #4. Operating temperatures will be 228°F on rolls #1 and #3 and 200°F on rolls #2 and #4. Nominal gap settings between #1 and #2 is .052", between #2 and #3 is .046" and the gap between #3 and #4 is .040".

Shep Lampkin SUN 143-33 15 April 1970

Detailed Specification for Four Roll Inclined Z Calender

General:

A 24" x 46" 30° inclined Z powder calender. The calender to have drilled rolls, flood lubrication, motorized explosion-proof, Class I, Group D, Class II, Groups E, F & G, adjusting motors, hydraulic preload, a uni-drive and miscellaneous hoppers, swinging guides, scrapers and slitters, for general operating temperatures below 260°F.

Speed:

Calender to be arranged for independent drive of each roll with rolls #1 and #3 to have a maximum surface speed of 120 fpm and rolls #2 and #4 to have a maximum surface speed of 140 fpm. Driving #1 roll, a 30 hp motor with a top output speed of 850 rpm. Driving #2 roll, a 75 hp motor with a top output speed of 990 rpm. Driving #3 roll, a 50 hp motor with a top output speed of 120 rpm. Driving #4 roll, a 30 hp motor with a top output speed of 990 rpm. All motors to be constant torque and general purpose.

Frames:

Frames to be cast Meehanite, arch top, solid end, with rolls on a 30° incline. This means that a line drawn between rolls #1 and #2 would form a 30° angle with a horizontal line drawn through roll #2. No crossbars or tie rods to be installed between frames except for supporting hoppers and side guides. Frames shall be designed so as to allow the removal of the rolls through the bearing windows.

Bed Plates:

Frames to be mounted on cast stringer type bed plates and all of the hold down and foundation bolts and their plates to be supplied.

Rolls:

Rolls of chilled iron, drilled and ported below outer surface for optimum roll surface temperature control with three pass circulation, bored and fitted with rotary high pressure joints and internal piping. Roll surface to be ground to a No. 16 finish and the rolls shall be free of all plugs and pits.

Roll Journal Bearings:

Roll journal boxes to be cast, with full lined bronze bushings with lip type oil seals on inside and outside to retain the lubricant from the flood lubrication system. Boxes to be drilled to accept the controlled flow of lubricant, as well as for adequate drainage to reduce the danger of leakage.

Reduction Drive:

One parallel shaft uni-drive of the double reduction type capable of taking the individual inputs of motors listed under the speed paragraph and to deliver the proper rpm of the rolls for the specific calender speeds, all with a service factor of 2.0. Included on the uni-drive would be the necessary motor couplings for connecting the motors to this drive. The gearing to be cut double helical in a fabricated steel housing supported by antifriction bearings and equipped with its own lubrication system. Also to be included is a structural steel motor support to support the motors which will be connected to the uni-drive. The supports will be machined, drilled and foundation bolts supplied for installation in proper concrete bases.

Spindles:

Provide gear type spindles to drive from the output of the uni-drive to the calender. Spindles shall be capable of taking the torque output of the reducer and the misalignment which may result from the roll adjustment mechanisms. Length will be determined subsequent to final design of walls.

Seal Plate:

Design for seal plate to provide positive seal between calender room and motor room will be determined subsequent to final design of walls.

Bearing Preload:

All rolls will be preloaded directly from the roll journal to the side frames by means of full circle bronze bearings outboard of the main bearings and connected through hydraulic cylinders to the frame. The bearings to be flood lubricated and included in an extension of the main bearing boxes. Also, shall include hydraulic pump and reservoir for operation of preloading cylinder. Hydraulic pump will be located approximately 100 ft. from the calender in a nonhazardous location.

Roll Adjustment:

Individual motorized explosion-proof roll adjustment will be provided for each end of #1, #2, and #4 rolls. No. 3 roll is fixed. Motors shall be two speed, slow and fast, and explosion-proof, Class I, Group D, Class II, Groups E, F & G. Adjustment range to be from 0" to 0.125" with an acceptable tolerance of $\pm$ 0.001".

Roll Journal Lubrication:

A flood lubrication system for supplying a controllable flow of clean oil to the journal bearings, the preload bearings and the adjusting screws shall be provided. The system shall include a motor driven pump, (motor to be general purpose) oil sump with heating and cooling coils, filter, strainers, pressure switch controls, and the necessary valves and gauges for proper operation of the lubrication system to the bearings. The lubricating pump will be located approximately 100 ft. from the calender and in a nonhazardous location. The location of the pump will not permit a gravity flow of lubricating oil from the calender to the pump.

Side Guides:

Two (2) sets of stainless steel, Type 304, 3/4" thick, hinged, with adjustable spacing from 39" to 43" side guides mounted between rolls #1 and #2 and between #3 and #4. Design of plows to be mounted on the guides will be provided by Hercules Incorporated.

Scrapers:

Two (2), air operated mounted in two o'clock position on #2 and #4 roll.

Hopper:

Two (2), 304 stainless steel hoppers; one (1) hopper is to funnel paste to the bite of #1 and #2 rolls. One (1) hopper is to direct material scraped from #2 roll down to the bite between #3 and #4 rolls.

Safety Features:

Cable type safety throwout mechanism with explosion-proof switch, one on each side of the calender.

Roll Heating System:

Provide roll temperature system with controls of sufficient capacity to maintain operating temperature as specified in the general operating condition section.

Two Roll Calender

Description of Material to be Rolled:

The material to be rolled is a plastic explosive sheet 42" wide that has been folded into a 12" wide sheet. The density of the material is approximately 0.056 lb/cu.in.

Description of Function Calender is to Perform:

A 25 lb. sheet of plastic explosives will be received and guided by a hopper into the bite of the two (2) rolls where it will band around the bottom roll. There are two (2) stationary knives on the bottom roll that slit the material as it comes around the roll. The material is continually fed into the bite with a continuous strip being taken off between the two slitter knives. The excess material remains banded to the bottom roll and is plowed back into the bite as the roll continues to turn.

General Operating Conditions:

The operating speeds on the calender will be approximately 40 fpm on both rolls with operating temperature of 160°F on top roll and 140°F on bottom roll. Nominal gap setting is 0.075".

Detailed Specification for Two Roll Calender

General:

A 2 roll 18" x 20" inclined powder calender for operations not exceeding 260°F. The calender to have drilled rolls, flood lubrication, motorized explosion-proof, Class I, Group D, Class II, Groups E, F & G, adjusting motors, hydraulic preload, uni-drive for independent motor drive of each roll, and miscellaneous hoppers, scrapers, and slitters.

Speed:

Calender to be arranged for maximum surface speed of 120 fpm. Speed to be variable with approximate range of 1 to 7 through constant torque general purpose motor.

Frames:

Frames to be of cast Meehanite, arch top, solid ends, with no cross or tie bars except for supporting hoppers, scrapers or knives. Frames shall be designed so as to allow the removal of the rolls through the bearing window.

Bed Plates:

Bed plates are to be the same as specified in 24" x 46" calender specification.

Rolls:

Rolls to be the same as specified under 24" x 46" calender except for the diameter and face which would be 18" x 20".

Journal Bearings:

Journal bearings to be the same as those specified under the 24" x 46" calender.

Reduction Drive:

One parallel shaft uni-drive arranged to give maximum roll speeds of 120 fpm with a 15 hp general purpose motor. Input to uni-drive shall be 1200 rpm. Gears to be mounted on shafts supported by antifriction bearings and enclosed in a structural steel case arranged for independent flood lubrication.

Spindles:

Spindles to be the same as specified under the 24" x 46" calender specification.

Seal Plates:

Seal plates to be the same as specified under the 24" x 46" calender specification.

Bearing Preload:

Top roll to be preloaded hydraulically and to the same specification as described under the 24" x 46" calender specification.

Roll Adjustment:

The top roll to have individual motorized roll adjustment on each end and to the same specification as described under the specification for the 24" x 46" calender.

Roll Journal Lubrication:

Roll journal lubrication system to be the same as specified under the 24" x 46" calender specification.

Hopper:

One (1) 304 stainless steel hopper to be arranged to take a 12" wide folded sheet from a conveyor above the #1 roll and arranged to provide a bank between rolls #1 and #2.

Side Guides:

One (1) set of 304 stainless steel swinging guides similar to those used on the 24" calender with the added feature of being adjusted a minimum of 3" horizontally.

Scraper:

One (1) adjustable scraper mounted in such a way as to have approximately .005 clearance from roll #2 surface and mounted in the 3 o'clock position.

Slitter Knives:

An arrangement of mechanically adjustable slitter knives. Knives to be capable of cutting a strip 3" to 10" wide from the center of #2 roll. Knives to be located at the bottom of #2 roll.

Roll Heating System:

Provide roll temperature system with controls of sufficient capacity to maintain operating temperature as specified in the general operating section.

Task B-4

Criteria for Strip Winder

Objective:

To prepare the criteria for a winder that will wind the propellant strip into a carpet roll for subsequent extrusion into grain blanks. Research of the winder market will be made to determine the availability of an acceptable "off-the-shelf" winder incorporating the latest "state of the art" in winder design.

Specification:

The following specification was written to meet the objective. Market research indicated that an "off-the-shelf" winder, meeting all of the requirements, did not exist, but eleven manufacturers indicated they could make modifications to their equipment to comply.

Automatic Carpet Roll Winding Machine

Description of Material to be Wound:

The material to be wound is a plastic explosive 4 to 6 inches wide and .080 to .110 inches thick. The machine is to be capable of winding material within the above ranges into rolls ranging from 10 to 21 inches in diameter. The weight of the rolls will be 25 lb. for 10" diameter and 95 lb. for 21" diameter. The temperature of the material to be 90°F to 120°F. Tensile strength of the strip is approximately 10 lb./in. of width.

Description of Function Machine is to Perform:

A continuous strip of material will be fed by powered conveyor to the automatic winder at the rate of 0 to 100 feet per minute. The winder shall take the leading edge of the strip and wind it into a roll with no greater than a 1" diameter hole in the center. After the required roll diameter has been obtained, the strip shall then be cut. The following end shall then be used to start the winding of a new roll. During the cutting operation, a solvent (furnished by Hercules) shall be sprayed on the material so as to bond the loose end to the roll to prevent the unwinding of the roll while in transit. The spraying of the solvent shall not exceed one (1) revolution of the roll. A 50 pound force over a 2 x 2 inch area shall be applied for a period of 30 seconds to the loose end after the solvent has been applied. After the roll has been wound and the loose end bonded to the roll, the roll shall be automatically ejected horizontally onto a conveyor (furnished by Hercules). The winding of the roll shall be done by means of surface winding.

Special Limitations and Requirements:

1. Open friction slip clutches are not permissible.
2. Clutches that will have a heat buildup are not permissible.
3. Sliding metal parts shall be avoided.
4. All bearings are to be sealed and nonlubricating type.
5. All cylinders shall meet JIC standards.
6. The machine shall be completely automatic. There will be no manual assistance of the machine permitted. Not even for startup.
7. Guards are to be provided for all moving parts and so constructed that confinement of powder particles cannot occur.
8. All electrical equipment that will be in the same room as the winder shall be UL approved for Class I, Group D and Class II, Groups E, F & G.
9. Operating temperature of equipment, except drive motors, shall not exceed $150^{o}F$.
10. Construction of the machine to be of noncorrosive nonsparking material.
11. The length of the machine shall not exceed six (6) feet in either direction from the center line of roll ejection.
12. The design of the winder shall be such that the roll will be ejected from the right side in one application and from the left side in another application.
13. All material used in the construction of the winder shall be conductive.
14. The use of metal castings should be avoided.
15. The winder should be designed for ease of cleaning and to prevent the entrapment of explosive material in blind holes, threads, corners, crevices, ledges, piping, fittings, etc. Where traps, such as blind holes cannot be avoided, weep holes or other means of access for flushing and cleaning should be provided.
16. Welding shall be kept at a minimum.
17. All welds shall be accessible for surface examination.
18. All controls shall be designed to be fail safe.
19. Final winder design and description of operation shall be approved by Hercules Incorporated prior to equipment fabrication.

Utilities Available:

1. 100 psi air.
2. 70 psi water.
3. 440 3ø 60 cycle electricity.
4. 110 1ø 60 cycle electricity.

Task B-5

Design of Dust Collection Systems

Objective:

To design systems collecting dust and fumes at various points in the process to eliminate air pollution and abate contamination of process water.

Discussion:

The collection systems for the various rooms were specifically engineered for each room according to the criteria as outlined in the Tenth Edition of "Industrial Ventilation" published by the American Conference of Governmental Industrial Hygienist. There are four (4) separate systems in each roll line.

The systems are located in each room where transfer of paste occurs from one means of conveyance to another and where exhaust fumes are generated. Pick up ducts are located adjacent to the equipment that is transferring paste thereby generating dust or adjacent to fume producing equipment. After the dust and fumes are taken into the pick up ducts and as soon as they are in the horizontal duct run they pass by nozzles spraying water at 30^{o} to the direction of air flow. The water nozzles continue to spray all along the duct system to the air scrubber. Inside the air scrubber, the dust and fumes are removed from the air and flow in the scrubber effluent in open gutters to sumps for accumulation and disposal. No single system serves two rooms.

Drawings:

SK-SAAP 3086 Typical Pipe & Spray Nozzle for Air Scrubber

Specification:

The specification for the air scrubber is as follows:

Air scrubber with fan and drive to scrub ventilation exhaust gases and dust from a paste rolling operation and paste transfer point.

Material to be scrubbed.
Paste dust - paste is a mixture of nitrocotton, nitroglycerin, and other chemical additives to make a damp sawdust like material. Bulk density of the paste is 20 lb/ft^3. Particle size of dust is as follows: 9% is smaller than 74 microns, 15% is 74 microns, 68% is between 75 and 295 microns, 8% is above 295 microns.

Exhaust gases - The exhaust gases are a high boiling temperature mixture of water vapor, nitroglycerin vapor, and plasticizer vapor. The temperature of the mixture is approximately 220°F. The specific gravity (air = 1.00) of the gas is 1.35.

Operating Conditions

1. 2500 scfm to 3500 scfm with normal operating condition 3000 scfm.
2. 3 to 7 inches of water pressure loss in ducts prior to the scrubber. Normally operating at 3.75" water.
3. 200°F maximum air temperature entering scrubber.
4. Scrubbing water will be on a once through basis.
5. A minimum of 50% of makeup water will come through the ducts with the inlet gases.
6. Estimated average solids to be removed is 10 lb/hr. 90% of solids removal rate will occur in a 5 second period every 2 minutes.

Construction of Scrubber

1. Have no internal moving parts.
2. Have provisions for continuous flushing of internal surfaces that could be in contact with paste dust or exhaust gases.
3. Shall be mild steel construction.
4. All welded construction.
5. All welds to be continuous, ground, and with no surface pits or pockets.
6. All interior welds shall be dye penetrant checked to assure that no cracks or pits are present.
7. Have a minimum of one (1) access - inspection doors. Door t be no smaller than 18" square and shall be gasketed and bolted onto the scrubber.
8. Shall have a hopper bottom and standard 3" welding neck flange for continuous discharge.
9. Shall include structural support with provisions for fastening to the floor, and to maintain a 24" clearance between 3" flange and floor.
10. Shall include flanged inlet and outlet gas connections. See attached sketch for locations.
11. Shall include an automatic water level controller to maintain the proper water level in the scrubber by controlling the makeup water flow rate.
12. Exterior shall be painted with a 30-minute fire retardant propellant compatible high gloss white paint.
13. Avoid the usage of electrical controls wherever possible. All electrical components that are used shall be UL approved for Class I, Group D, Class II, Groups E, F, & G locations.

Fan Construction

1. Fan blades and housing shall be aluminum welded construction.
2. Fan shall be belt driven.
3. Fan will be remotely located from the scrubber.
4. Fan electrical shall be weatherproof for outside use.

Available Utilities

1. 5 psi steam
2. 80 psi air
3. 440 volt, 60 cycle, 3 phase
4. 80 psi water

Vendor shall furnish a written guarantee that the scrubber is no less than 99.5% efficient in the removal of contaminants from the inlet gases.

Task B-6

Criteria for Metal Detector

Objective:

To prepare the criteria for a detector that will scan the paste as it passes under the detector and actuate a paste reject system when tramp metal is present.

Specification:

Electronic Metal Detector

Performance of Metal Detector:

Metal detector shall detect and indicate the presence of ferrous and nonferrous metallic particles in a nonmetallic material. The material is an explosive mixture of nitrocotton and nitroglycerin and will be 20" wide by 1-3/4" deep on a 24" wide nonconductive conveyor belt. Conveyor will operate in a range of 5 to 40 fpm. The detector shall detect metallic materials from .010" in diameter and up.

General:

The detection system shall be UL approved to meet Class I, Group D, Class II, Groupd E, F, & G and shall have built in immunity to ground current loops. The inspection head will be located 4 ft. from any moving metal mass and 3 ft. from stationary metal masses.

Power Supply and Controls:

A power supply and detector control shall be supplied to control the operation of the metal detector. Also furnish built-in meter and adjusting controls to calibrate and adjust the sensitivity of the unit. Controls will be located remotely and shall include an 0 to 3 minute time delay. Controls shall be 110 volt single phase general purpose. Pilot lights and switches to indicate and control the on-off condition of operation.

Unusal Operating Conditions:

The detector head will be subject to occasional flash fires which will be extinguished by deluge sprinkler system. It is expected that the detector will be designed in such a manner that after the sprinklers have been reset, the detector will be operational.

Task B-7

Criteria for Dielectric Heater

Objective:

To prepare the criteria for a dielectric heater implementing the latest "state of the art" in heater design.

Specification:

Dielectric Heating System

Description of Material to be Heated:

The material is a mixture of nitrocotton and nitroglycerin that is best described as damp saw dust and is referred to as paste. Density of paste is approximately 20 lb/cu. ft. and contains approximately 10% water.

Description of Function Heater is to Perform:

Heater is to heat a 25 lb. charge of paste from 60°F to 180°F in one minute or less. Paste will pass under the heater on a 24" wide conveyor belt. The paste on the belt will not exceed 20" in width or 2" in depth.

Detailed Specification of High Frequency Generator

Construction:

Housings containing power supply, oscillator, output tuning section, controls and electrode applicator shall be all welded aluminum construction. Power supply and oscillator shall be housed in one common housing. The power supply-oscillator housing and electrode applicator housing shall include provisions for lifting by hoist. Maintenance access panels shall be provided in all housings.

Output Power Level:

Power output, from minimum to full rating to be controlled by push buttons remotely located on main control console. Output level shall be automatically maintained as product condition varies.

Input Power:

Power available is 440 volts, 60 cycle, 3 phase.

Safety Features:

Radio frequency power will be started by manual button remotely located. Radio frequency power shall have capability of being externally interlocked with limit switches. High voltage grounding devices, panel interlock switches, overload relays and circuit breakers shall provide personnel protection. The high voltage power supply shall include a time delay circuit to permit tube warm-up before high frequency power can be turned on. An arc detector device to operate in less than two thousandths of a second to stop the oscillator and remove R.F. voltage in the event of an arc in the electrode system or in the material being heated shall be provided.

Meters and Pilot Lights:

Grid current and kilovolt meters shall be located on the power supply-oscillator. Grid current and kilowatt meters shall be on the remotely located main control console. All meters will reflect current, voltage, and wattage on both input and output circuitry. Pilot lights indicating power on and ready for operation at the power supply-oscillator and main control console shall be provided. Also a 12" long indicator light at product input of electrodes to indicate that radio frequency is present.

Transmission Line:

The transmission line and radio frequency shielded connection between the applicator and power supply-oscillator shall be designed and fabricated in such a manner that a vapor tight seal will be formed between the applicator room and power supply-oscillator room. The vendor shall furnish to Hercules Incorporated fabrication drawings of radio frequency shielded connection and dielectric applicator for approval prior to fabrication.

Air-conditioning:

Air-conditioning equipment shall be furnished to cool the power supply-oscillator and output capacitor. Available water supply is 10 gpm at 80 psig and 85°F.

FCC Certification:

The dielectric heating system shall be designed in such a manner that no external shielding is required to meet the requirements of Part 18 of the Federal Communications Comission Regulation. Federal Communication Commission Compliance Certification shall be furnished by the vendor.

Task B-8

Design of Process Controls

Objective:

To design the controls for process equipment, complete with sequence and sprinkler interlocks, utilizing the latest "state of the art" in equipment. The system shall be designed for remote control automatic operation including "fail safe" design for safety.

Drawings:

The following drawings were prepared to meet the objective parameters and are a part of Task B-10 Facility Design Criteria.

SK-SAAP 3113	Composite System Diagram
SK-SAAP 3117	Process Motor Control Wiring Diagram
SK-SAAP 3118	Nonprocess Motor Control Wiring Diagram
SK-SAAP 5112	Process Control Deluge System Wiring Diagram
SK-SAAP 3120	Electrical Controls

Task B-9

Design of Half Charge Paste Buggy

Objective:

To design a buggy to transport half a blender charge (approximately 500 lbs.) of paste. The buggy shall be nonsparking nonferrous material capable of being loaded and dumped remotely and automatically.

Drawings:

The following drawing was prepared to meet the above objective.

SAAP 7826 Mechanized Roll Half Charge Buggy Assembly

This drawing and its associated drawings were discarded when Task B-10 was subsequently developed. In Task B-10 it became desireable to feed paste to the mechanized roll in smaller increments to minimize the amount of propellant at any one point in the process.

Shep Lampkin SUN 143-33 15 April 1970

Task B-10

Facility Design Criteria

Objective:

To prepare facility design criteria for a remote controlled automatic mechanized roll complex. The design to incorporate the latest "state of the art" equipment meeting all requirements of safety, production requirements, and product specifications. The criteria for the facility will be complete to the point that the Corps of Engineers may use it to proceed with the preliminary design of construction drawings.

Design Criteria:

The following design criteria was prepared to meet the requirements of the objective.

Design Criteria Memorandum

1. General

a. Installation: Sunflower Army Ammunition Plant

b. Project: AMC Project No. 5712373, Modernization of Solventless Propellant Manufacturing Facilities (Phase I)

c. Project Description (Scope of Work):

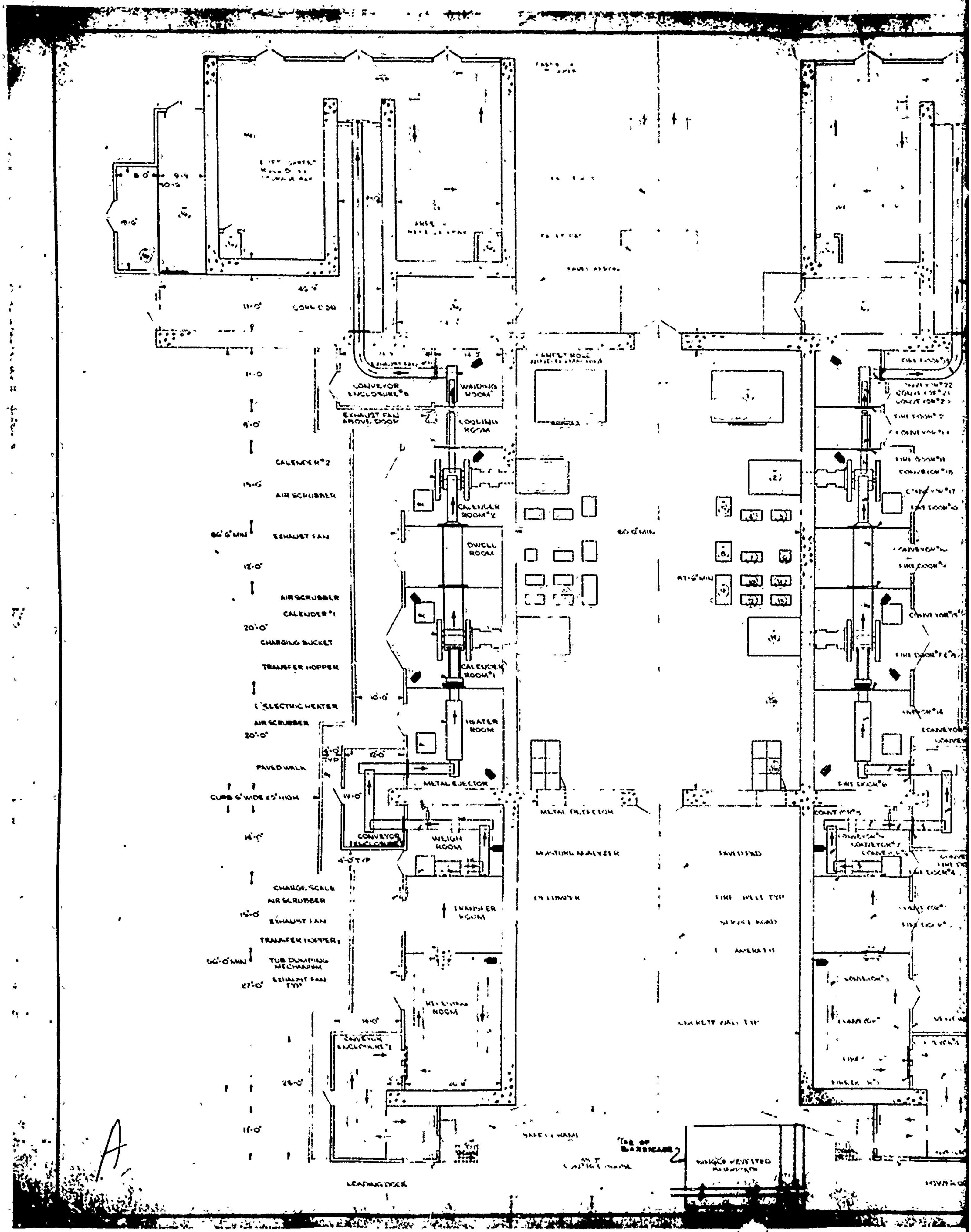
This project consists of the construction of two (2) solventless, reference drawing SK-SAAP-3121, propellant manufacturing complexes and their remotely located control rooms. Construction of the solventless propellant manufacturing complexes will be accomplished in three phases. Phase I will include the construction of the structure to house all three phases, with installation of temporary equipment on Phase I, pending funding of Phase II & III. Phase I encompasses the mechanized roll where the paste is converted to the colloided carpet roll for extrusion in manually operated conventional presses situated at another location. Phase II encompasses the subsequent location of the extrusion presses at the end of the mechanized roll line allowing the carpet rolls to be automatically fed to the press, the press automatically loaded and extruded, grains automatically cut and annealed, all remotely controlled. Phase III eliminates the manual handling of paste, as done in Phase I & II, by the incorporation of a continuous dewater paste blending operation which is automatic and remotely controlled. Each phase substantially decreases the personnel exposure to propellant over the existing manual conventional method.

d. Estimated Cost: $6,907,800

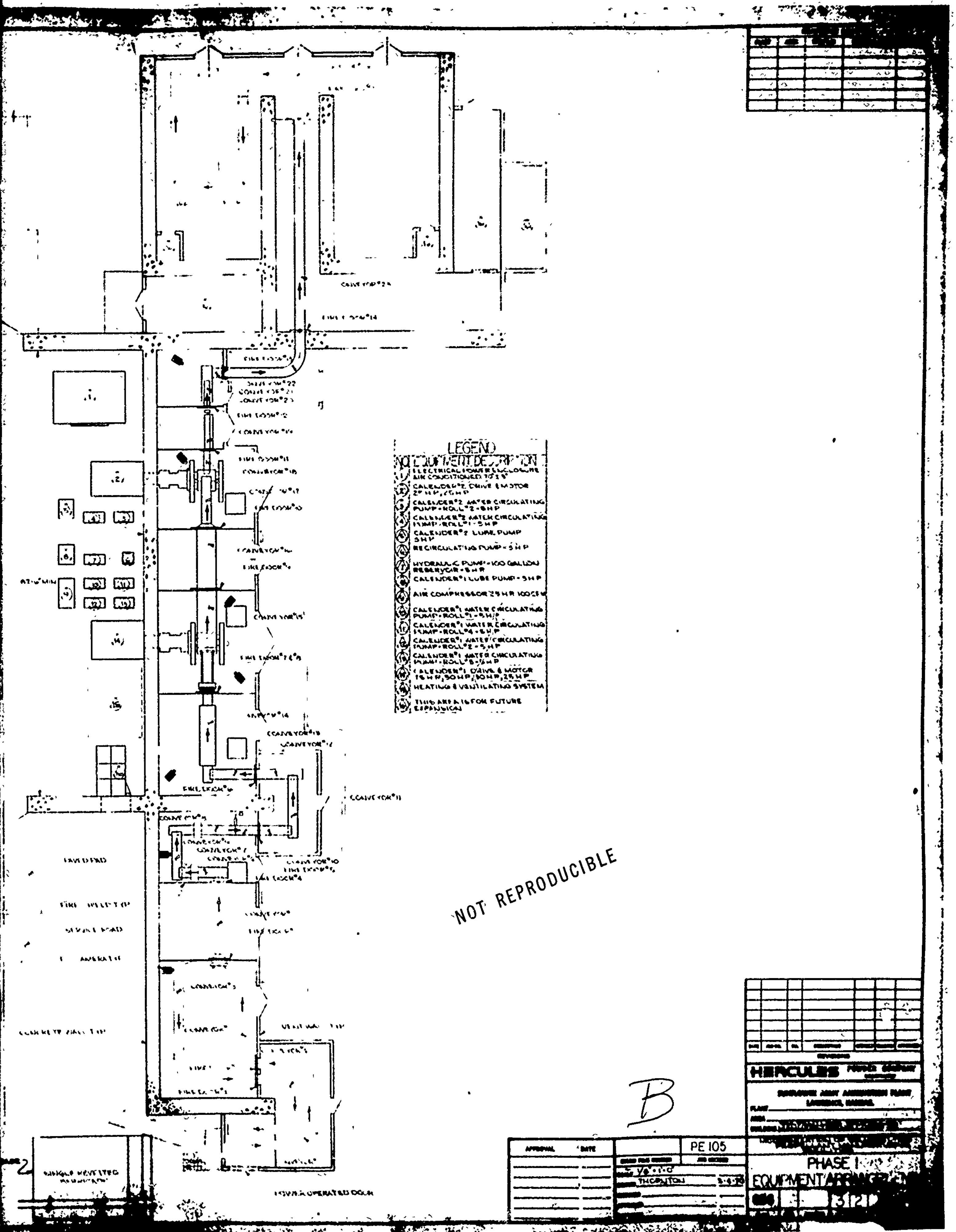
e. Date Memorandum was Prepared: 25 February 1970

f. Inclosures:

(1) SK-SAAP 3111 Plot Plan
(2) SK-SAAP 3119 Control House
(3) SK-SAAP 3114 Solventless Propellant Manufacturing Facility - Phase I



CORRIDOR
CONVEYOR ENCLOSURE #5
WINDING ROOM
EXHAUST FAN ABOVE DOOR
COOLING ROOM
CALENDER #2
AIR SCRUBBER
EXHAUST FAN
CALENDER ROOM #2
DWELL ROOM
60'-0" MIN
AIR SCRUBBER
CALENDER #1
CHARGING BUCKET
TRANSFER HOPPER
CALENDER ROOM #1
ELECTRIC HEATER
AIR SCRUBBER
HEATER ROOM
PAVED WALK
METAL EJECTOR
CURB 6" WIDE X 3" HIGH
CONVEYOR ENCLOSURE
WEIGH ROOM
METAL DETECTOR
MOISTURE ANALYZER
PAVED PAD
CHARGE SCALE
AIR SCRUBBER
EXHAUST FAN
TRANSFER ROOM
TRANSFER HOPPER
TUB DUMPING MECHANISM
EXHAUST FAN TYP
RECEIVING ROOM
CONVEYOR ENCLOSURE #1
TOE OF BARRICADE
LOADING DOCK
A



NOT REPRODUCIBLE

f. Inclosures (contd.)

(4) SK-SAAP 3102 Roll Rooms Equipment Arrangement -
(5) SK-SAAP 3101 Receiving & Transfer Room Equipment Arrangement
(6) SK-SAAP 3103 Press & Annealing Room Equipment Arrangement
(7) SK-SAAP 3104 Press Bay Equipment Arrangement
(8) SK-SAAP 3105 Expeller & Blender Room Equipment Arrangement
(9) SK-SAAP 3107 Roll Rooms Deluge Sprinkler System
(10) SK-SAAP 3106 Deluge Sprinkler System
(11) SK-SAAP 3108 Press Bays Sprinkler System
(12) SK-SAAP 3109 Sprinkler System
(13) SK-SAAP 3110 Sprinkler System
(14) SK-SAAP 3113 Composite System Diagram
(15) SK-SAAP 3117 Process Motor Control Wiring Diagram
(16) SK-SAAP 3118 Non-process Motor Control Wiring Diagram
(17) SK-SAAP 3112 Process Control - Deluge System Wiring Diagram
(18) SK-SAAP 3120 Electrical Controls
(19) SK-SAAP 2391 Typical Sump
(20) SK-SAAP 3051 Building Plan & Equipment - Safety Review
(21) SK-SAAP 3052 Safety Review

2. Safety Approvals:

a. Siting: The drawings for site approval were submitted 30 January 1970.

b. Plans & Specifications:

Plans and specifications must have a final safety review and approval before a construction contract can be awarded. Therefore, plans 60 to 70 percent complete should contain the information outlined in Paragraph 527G, AMCR-395-224, to permit this review, before final design is completed.

c. Materials:

All materials proposed to be used on this project shall be compatible with N-5 propellant. Compatibility tests on proposed material, upon request and prior to use, will be made by the Operating Contractor. Allow two (2) weeks for testing.

3. Functional Criteria:

In preparing this criteria, an attempt was made to provide all of the information available as to the functional purpose of this facility, special features to be included, and detailed requirements. The design agency is requested to recommend, for consideration, modifications wherever greater economy in design, construction, operation, or maintenance may be obtained without detriment to safety, product quality, or functional efficiency.

a. General:

All design and construction will comply with AMCR-395-224, AMCR-385-227 and TM5-1300 and National Electric Code. Where the aforementioned documents do not specifically indicate the design criteria and the design criteria does not appear on the drawings or in this memorandum, then published and accepted standards of construction will be used. The complex houses the process equipment to convert a mixture of nitrocotton, nitroglycerine, plus additives, from a damp saw dust like material (colloquially referred to as "paste") to a colloided plastic type sheet which is slit into a strip, wound into rolls, and extruded through a press, yielding the final product-rocket motor propellant grain blanks. The sequence of operations for each phase are as follows:

Sequence of Operations - Phase 1

The paste will be delivered to the weather protected loading dock by the paste vehicle operator when he observes the green light on the loading dock. The green light is an indication that four tubs of paste are needed at the loading dock on conveyor #1. After the operator places four full tubs on conveyor #1, he removes the lids, loads the four empty tubs from conveyor #4, closes the door to the loading dock and drives the paste vehicle to the next line requiring paste.

The four tubs of paste are conveyed on conveyor #1 past a sensor that opens fire door #2 onto conveyor #2. When the fourth tub passes a sensor at the beginning of conveyor #2, fire door #2 closes and conveyor #1 stops and the green light comes on. Conveyor #1 is interlocked with the powered entrance door to the loading dock to prohibit conveyor #1 from running while the operator is on the dock. The full tubs of paste continue on conveyor #2 until they reach the indexing mechanism prior to the dumping mechanism at which time conveyor #2 stops.

When the level of paste in the delumper hopper reaches the critical low level, conveyor #2 indexes a full tub on the dumping mechanism, pushing the empty tub off the dumping mechanism onto conveyor #3. Conveyor #3 indexes with conveyor #2 until four empty tubs are on conveyor #3, at which time, conveyor #3 moves the tubs through fire door #1 onto conveyor #4 and fire door #1 closes. Conveyor #4 runs until the tubs pass a sensor to stop conveyor #4. Fire door #3 opens, and the dumping mechanism dumps the tub into the transfer hopper, after the dumper has completed its cycle, fire door #3 closes, fire door #4 opens and conveyor #5 moves the paste into the delumper hopper. When the level control on the transfer hopper indicates it is empty, a time delay keeps conveyor #5 running until all the paste has passed through fire door #4 after which conveyor #5 stops and fire door #4 closes.

When scale conveyor #9 is empty, the delumper, conveyor #6, 7 & 8 start running. The paste passes from the delumper hopper through the delumper onto conveyor #6, under the moisture analyzer, onto conveyor #7, and then onto conveyor #8 under the metal detector. If the paste is contaminated, an ejector at the end of conveyor #8 is activated and rejects the contaminated paste. If the paste is clean, conveyor #8 feeds paste onto scale conveyor #9 until the charge weight has been reached as determined by the moisture analyzer. When the desired charge weight is on conveyor #9, the delumper, conveyor #6, 7 & 8 stop and fire door #5 opens, then conveyor #9 speeds up and the paste passes through fire door #5 onto conveyor #10. When conveyor #9 is empty, fire door #5 closes and the weigh cycle repeats.

The paste on conveyor #10 moves onto conveyor #11 and then #12 through fire door #6 and onto conveyor #13 and fire door #6 closes. Conveyor #13 deposits the paste on conveyor #14 where it passes under leveling rollers and under the dielectric heater. As the paste comes from under the heater, fire door #7 opens and the paste passes into the charging hopper. When the charge is in the hopper, fire door #7 closes. When the charging bucket is in position, fire door #8 opens and the charge falls into the charging bucket and fire door #8 closes. The full charging bucket elevates to the dumping position above the top set of rolls on calender #1. The charging bucket dumps the paste on the top set of rolls and returns to its filling position beneath the charging hopper.

The paste colloids on the top set of rolls and is worked in two bites for the duration of the cycle time, after which, the colloided sheet is cut from the top set of rolls on calender #1 and goes to the bottom set of rolls for additional working in one bite for one time cycle. At the end of the time cycle, the sheet is cut off the bottom set of rolls to make room for the top roll sheet. When the sheet is cut from the bottom set of rolls, fire door #9 opens and the sheet is carried on conveyor #15 through fire door #9 onto conveyor #16, when the sheet is entirely on conveyor #16, it stops and fire door #9 closes. The sheet dwells on conveyor #16 for one time cycle, then fire door #10 opens and conveyor #16 starts and the sheet passes through fire door #10 through the folding chute onto conveyor #17. After the sheet passes fire door #10, it closes and conveyor #17 slows down to feed the sheet onto calender #2.

A continuous strip is cut from calender #2 and is carried on conveyor #18 through fire door #11 onto conveyor #19 through the cooling room through fire door #12 onto conveyor #20 into the automatic carpet roll winder. Fire doors #11 & #12 are guillotine type doors and are normally open but are activated and closed by a sprinkler trip. The strip is wound into the prescribed carpet roll size, the end of the strip sealed to the carpet roll, and the roll ejected from the winder onto conveyor #21. When the carpet roll is ejected from the winder, fire door #13 opens and the roll is transferred to conveyor #22 and fire door #13 closes. Conveyor #22 carries the roll to and through fire door #14 onto conveyor #23. After the carpet roll passes fire door #14, it closes and the roll travels to fire door #15 which opens for the roll to go onto conveyor #26 and fire door #15 closes. Conveyor #26 puts the carpet roll on a gravity storage conveyor to await placement in the carpet roll buggy to be taken to the press area.

Sequence of Operations - Phase II

Phase I and Phase II are identical from paste receiving through carpet roll winding, after winding Phase II operates in the following manner. The strip is wound into the prescribed carpet roll size, the end of the strip sealed to the carpet roll, and the roll ejected from the winder onto conveyor #21. When the carpet roll is ejected from the winder, fire door #13 opens and the roll is transferred to constant speed conveyor #22 and fire door #13 closes.

Conveyor #22 moves the carpet roll to fire door #14 which is opened by the carpet roll passing a sensor. The carpet roll is then transferred to conveyor #23 and fire door #14 closes. This is repeated until three carpet rolls are on conveyor #23. Conveyor #23 then goes to fast speed and fire door #15 opens. Fire door #15 remains open until the third carpet roll has passed on to conveyor #24, then closes at the same time the gate on conveyor #24 moves to the opposite position to divert the next three carpet rolls to the alternate press.

The three carpet rolls move onto conveyor #26 and are carried at the required speed to the automatic loader where each roll is positioned in the loader and inserted into the basket of the press. After insertion of the third carpet roll, the press begins the extrusion cycle. As the extrusion begins, the automatic cutter begins to cut the extrusion to the required grain length. The grain drops from the cutter onto conveyor #28 and proceeds to fire door #16. If a grain is on conveyor #28 and also conveyor #27 and reaches the intersection to conveyor #29 at the same time, conveyor #28 will stop for a period necessary for the grain on conveyor #29 to pass, then conveyor #28 begins and the grain passes through fire door #16 onto conveyor #30 and then conveyor #31. Conveyor #31 carries the grain under the metal detector to conveyor #32 where defective grains will be rejected. Acceptable grains will pass through fire door #17 onto conveyor #34 and under conveyor #35 through the annealing dielectric heater. The grains come out of the heater and are picked up by conveyor #36 and transferred to conveyor #37 which takes the grain to the skid loading house.

Sequence of Operations - Phase III

Beginning at the weigh room, the operations for Phase III are the same as for Phase I & II. Phase III requires the removal of Phase I & II equipment from the receiving room and transfer room. The receiving room is converted to a de-watering room and the transfer room becomes the blending room. Paste slurry will be piped to the de-watering mechanism from the Paste Area. The paste slurry will pass through the de-waterer onto a conveyor and to the blender. The paste will be blended and conveyed to the delumper and then follow the same sequence of operations as in Phase I & II.

b. Siting:

The site selected as shown on SK-SAAP 3111 was chosen because of its central location to prior and subsequent operations in the manufacturing process. The site also affords future expansion without jeopardizing existing adjacent production facilities.

c. Floor Plan:

The floor plan of the complex as shown on SK-SAAP 3114 and associated drawings. The type of work to be performed is remotely monitored automatic material processing. The floor plan of the remote control room is shown on SK-SAAP 3119.

d. Personnel Occupancy:

During Phase I, one operator will be in the press room for approximately 1/4 hour every 1½ hours, otherwise no personnel will be in the complex while material is being processed. During Phase II & III operation, no personnel will be in the complex. It is expected that six operators per shift will be in the control room.

e. Walls:

Walls shall be designed to meet the requirements of TM5-1300. Blow out walls shall be constructed of nonflammable materials. Fire shields shall be of nonflammable material, as thin as possible, and of sufficient strength to support fire door closure apparatus and sprinklers. Flush type construction should be used and horizontal ledges shall be avoided or beveled. No windows shall be installed in the complex. Void spaces such as double walls, suspended ceilings, crawl spaces should be avoided. Where they cannot be avoided, they shall be sealed off.

f. Interior Finishes:

Interior wall finishes in the process complex shall be free of voids and all joints shall be sealed with an approved N-5 propellant compatible silicone rubber sealer. All walls shall be painted with a 30-minute fire resistant N-5 propellant compatible high gloss paint. Unless otherwise shown on the drawing, the floor finish shall be nonskid, nonsparking, conductive, grounded, and sloped to the gutter 1/8" per foot. Intersection of walls and floor shall be coved and construction joints sealed. Conductive floors shall be tested for electrical resistance per AMCR-385-224 and shall not exceed 250,000 ohms.

g. Design Loads:

The design loads are to be determined by the designer and shall conform to TM5-1300, AMCR-385-224, all applicable federal, state and local codes. Weight of AMC equipment is nominal except the calenders and extrusion presses. Calender #1 weights 35 tons, its gear drive in motor room weighs 15 tons. Calender #2 weighs 15 tons, its gear drive 10 tons. The extrusion press weighs 43 tons.

h. Loading Docks:

Loading docks are required at each end of the complex as shown on Drawing SK-SAAP 3101 & SK-SAAP 3103. Loading dock to have reinforced concrete floor. Docks are to be lighted for night use. Curb rails and bumper shall be provided. Nonskid treads shall be provided on steps. All risers to be closed. Handrails shall be designed for a 50 lb/ft. horizontal load applied at the upper rail 42" off floor or 500 pound point load applied horizontally at any location to the bumper rail. All wood except handrails to be unpainted, except top rail shall be painted yellow. All nails and bolts exposed to walk area shall be countersunk. General framing shall conform with current structural design practice, lumber shall be treated with pentachloraphenal.

i. Roads:

Roads shall be designed as shown on SK-SAAP 3111 for 18000# per axle-limited traffic, two lane roads shall be 20'-0" wide, all shoulders to be 5'-0" wide. Roads shall be paved with nondusting pavement with 1/4" per foot crown over a subbase as required from soil analysis. Maximum grade shall be 5%. Approach areas to buildings be constructed of concrete. Road (turnouts) grades to building entrances and drive throughs shall not exceed 2% to a point 2'-0" from the entrance. A 1-inch rise should be provided in the 2'-0" of remaining roadway to minimize rain flow into a building drive through. Storm drainage should be collected in open ditches. Ditch slope should be a minimum of 0.5% and should not exceed a maximum of 5%. Where necessary to exceed this slope, (1) A lined ditch shall be provided, or (2) A 5% maximum slope shall be maintained by installing step-type retaining spillways. Roadways should be striped using a 4-inch wide strip along the centerline of all roads and to building entrances. A minimum of 4'-0" clearance shall be maintained from the edge of the pavement to any utility support or another obstruction.

j. Parking Areas:

Provide parking space for five (5) pickup trucks at each control house. Precast concrete wheel stop shall be provided for each space.

k. Landscaping:

There are no unusual requirements for landscaping, however, all uncovered ground should be graded for proper drainage and then fertilized and seeded.

l. Demolition:

If the buildings on the site have not been dismantled at the time of construction, the Contractor will dismantle all buildings. The accounts to be demolished are:

601-1 thru 6	7899-2	1994
5825	7833	308-2 & 3

Concrete above and one foot below grade shall be removed and disposed of in a designated fill area. Concrete below grade and in the area of new construction will be completely removed and disposed of in a like manner. All lumber and miscellaneous metal items, including poles, shall be delivered to the designated burning area. Burning will be done by the Operating Contractor. Upon completion of demolition, the area shall be cleaned of all debris. The area shall be graded to provide drainage.

m. Equipment:

The following equipment will be AMC furnished for Corps of Engineers installation. Quantity of equipment shown is for one line only. Total project consists of four lines.

(1) Receiving Room & Enclosure #1

Straight Conveyor Sections - 24" wide, metal belt, aluminum frame, sprockets, drives & controls.	10 each
90° Conveyor turn sections - 24" wide, metal belt, aluminum frame sprockets, drives & controls.	8 each

m. Equipment (contd.)

Fire door assembly, complete with cylinder.	2 each
Exhaust fan with motor.	1 each
TV Camera	1 each
Tub dumper assembly	1 each

(2) Transfer Room

Fire door assembly, complete with cylinder.	1 each
Loading hopper	1 each
Straight conveyor section 24" wide, belt, aluminum frame, drives & controls.	1 each
Exhaust fan with motor.	1 each

(3) Weigh Room

Fire door assembly, complete with cylinder	1 each
Delumper with drive.	1 each
Straight conveyor sections 24" wide, belt, aluminum frame, drive & controls	3 each
Scale, conveyor type with drive.	1 each
Moisture analyzer	1 each
Metal detector	1 each
Paste rejector assembly.	1 each

m. Equipment (contd.)

Air Scrubber with fan & motor	1 each
Air Scrubber duct system	1 each
Leveler roller	2 each
TV Camera	1 each

(4) <u>Enclosure #2</u>

Straight conveyor sections 24" wide, belt, aluminum frame, drives & controls.	3 each
Fire door assembly with cylinder	1 each

(5) <u>Heater Room</u>

Fire door assembly with cylinder	1 each
Straight conveyor sections 24" wide, belt, aluminum frame, drive & controls.	2 each
Leveler roller	1 each
Dielectric heater	1 each
Air Scrubber with fan & motor	1 each
Air Scrubber duct system	1 each
TV Camera	1 each

(6) <u>Calender Roll #1 Room</u>

Fire door assembly with cylinder	2 each
Air Scrubber with fan & motor	1 each
Calender charging bucket assembly	1 each

m. Equipment (contd.)

Straight conveyor section 48" wide, metal belt, aluminum frame, drive & controls	1 each
4 Roll 30° inclined "Z" calender with drive unit, motors, controls lubricating system, side plates, scrapper and hopper.	1 each
Calender heating system including pumps, heat exchanger control valves and control instruments	1 each
TV Camera	2 each

(7) Dwell Room

Fire door assembly with cylinder	1 each
Straight conveyor section 48" wide, metal belt, aluminum frame, drive & controls	1 each
Exhaust fan with motor	1 each

(8) Calender Room #2

Fire door assembly with cylinder	1 each
Folding chute	1 each
Straight conveyor section 24" wide, metal belt, aluminum frame, drive & control	1 each
Straight conveyor section 12" wide, metal belt, aluminum frame, drive & control	1 each
Air Scrubber with fan & motor	1 each
Air Scrubber duct system	1 each

m. Equipment (contd.)

Inclined two roll calender with drive unit, motors, lubricating system, side plates, hopper, scrappers and slitter knives.	1 each
Roll heating system including pumps, heat exchanger, control valves and control instruments.	1 each
TV Camera	1 each

(9) Cooling Room

Fire door assembly with cylinder	1 each
Straight conveyor section 12" wide, metal belt, aluminum frame, drive & control.	1 each
Exhaust fan with motor.	1 each

(10) Winding Room

Fire door assembly with cylinder	1 each
Strip winder with drive and control	1 each
Straight conveyor section 12" wide, metal belt, aluminum frame, drive & control	1 each
Straight conveyor section 24" wide, metal belt, aluminum frame, drive & control	1 each
TV Camera	1 each
Exhaust fan with motor.	1 each

m. Equipment (contd.)

(11) Conveyor Enclosure #3

Straight conveyor section 24" wide, metal belt, aluminum frame, drive & control	2 each
90° Conveyor turn section 24" wide, metal belt, aluminum frame, drive & control	1 each

(12) Corridor

Fire door assembly with cylinder	2 each
Straight conveyor section 24" wide, metal belt, aluminum frame, drive & control	3 each
90° Conveyor turn section 24" wide, metal belt, aluminum frame, drive & control	2 each

(13) Press Bay

Straight gravity conveyor systems 24" wide, roller, aluminum frame	3 each
90° Conveyor turn section 24" wide, gravity roller, aluminum frame	2 each

(14) Control House

Control console includes meters, recorders, indicating lights, etc.	1 each
TV Monitors	7 each
Electrical process control system & interlocks.	1 each

n. Water Supply:

Existing water supply is a 16" diameter line as shown on Drawing SK-SAAP 3111. The existing line will be relocated to maintain a minimum of 50 feet from explosive buildings. Water requirements are for normal consumption, for building cleanup and the following AMC equipment:

Weigh Room - Air Scrubber System - 15 GPM min.

Heat Room - Air Scrubber System - 15 GPM min.

- Air Conditioner (Dielectric Heater Power Supply) - 10 GPM min.

No. 1 Calender Room - Air Scrubber System - 25 GPM min.

No. 2 Calender Room - Air Scrubber System - 15 GPM min.

Press Room - Die & Basket Heating - nominal makeup.

Each Calender - Roll Heating System - nominal makeup.

Each Calender - Hydraulic Cooling System - 5 GPM.

One hose bibb will be required for each complex room for building cleanup.

o. Sanitary Waste:

No sanitary facilities are in the area. Facility should be designed for 40 people per shift, three shifts per day, seven days per week.

p. Industrial waste flow in gravity flow covered gutters, slopped ¼" per foot from each wing of the complex to be collected in a sump as shown on SK-SAAP 2391 to be located by the designer. Sumps shall be located at least 75' from the wing of the complex and such that effluent will flow in open ditches to natural drainage.

q. Fire Protection:

Existing water supply 16" diameter line at 80 psi pressure. Extra hazardous protection systems shall be as shown on Drawings SK-SAAP 3106 thru 3110. Criteria for the systems are as follows:

<u>Suprotex Deluge High Speed Protection</u>

(1) Fire protection systems to be Suprotex deluge high speed furnished by Automatic Sprinkler Company or equal. All rooms shall contain at least one (1) deluge valve.

(2) Deluge system to be tripped by rate of pressure rise, or manually from outside each door or from the control room.
(3) Each deluge system shall have a warning device and a red light located in the control room. The alarm will sound and the red light will go out when:

(a) Low water pressure.
(b) Low air pressure.
(c) System trips.
(d) O.S. & Y. valve to system is turned off.

(4) Air required for heat actuated device to be supplied by hydraulic air pump.
(5) Each deluge valve shall be controlled with an O.S. & Y. valve on water supply side of valve. The same O.S. & Y. valve shall control water to the primac valve.
(6) Deluge nozzles shall be:

(a) Automatic Sprinkler Company No. 668 or 668 WA (fog type).
(b) Deliver at least 15 gpm per nozzle at 40 psi.

(7) Deluge nozzles shall be installed in following locations:

(a) Over paths which personnel use when leaving the room. Nozzle openings to be 7'-0" from floor.
(b) Over and on the side of belt conveyors. The nozzles shall be placed approximately 2' or less, from one another on centerline of conveyor, and approximately 1'-6" from belt. Also, the nozzles on the side shall point at the belt return under the conveyor, and placed about 6 inches from belt.
(c) Open sprinkler heads shall be installed next to ceiling and be connected to deluge system.

(8) The following is required on all nozzles:

(a) Furnish discharge pattern, capacity, and water flow.
(b) Nozzles protecting equipment shall deliver water before ceiling nozzles operate.

(9) Deluge valve to be located as close to hazard as possible and at least 8'-0" from floor.
(10) No system shall be sized for more than 3000 GPM.
(11) All pressure gauges shall be located so they may be read while standing on floor under valve. Gauges shall have plastic nonshattering glazing.

(12) No more than three (3) heat actuated devices shall be allowed on one circuit.

(13) Piping shall be sized so that water may be delivered to the primac nozzles by either the deluge valve or the primac valve.

Ultra High Speed Protection

(1) Ultra high speed systems shall be "Primac System" as furnished by Grinnell Company.

(2) Primac system is to be supervised with alarm and red lights in control room.

(3) Each Primac system shall:

(a) Have a warning device and a red light (normally on) in control room to actuate when system trips.

(b) Have detectors arranged to operate in pairs so that it is necessary for two (2) detectors to see the fire before the system will operate.

(c) Have the control panel for each system located in the motor room. All panels shall be tagged and identified as to location of protection, and be capable of being actuated from motor room.

(d) Have the valve located approximately 5'-0" from floor, and be placed in horizontal run of pipe.

(4) Nozzle openings shall be close to the surface it is protecting, approximately 9 inches.

(5) Pressure gauges to be located so they may be read while standing in bay.

(6) Nozzles on Primac system are to be fed from deluge system as well as the Primac valve.

Criteria common to all Sprinkler Systems are as follows:

(1) Fire protection water main to a building shall have a supervised post indicator valve. Alarm shall sound in control bay and red light shall go off when PI valve is partly closed. PI valve to be located at least 50 feet from building.

(2) Holes through walls for pipe shall be oversize, so at least one inch thick mineral wool or equal may be packed around the pipe and pipe collars are to be sealed with Dow Corning Q-3-0079 (ready-to-use-sealant) or equal.

(3) All valves shall be identified in accordance with NFPA 13.

(4) Be designed so that in no case more than 50% of the available water is discharged.

(5) Have screwed malleable iron fittings up to 6" diameter and be in-

stalled for easy removal of pipe so that equipment may be maintained, repaired or replaced.

(6) Piping shall be painted with Cooks Company No. 801, Sunfast Red or equal.

(7) Nozzles shall deliver at least 15 gpm at 40 psi.

(8) Feed line to nozzle shall never be less than 1¼ inch diameter. Pipe drop to nozzle shall not be less than 1 inch diameter.

(9) Hydraulic calculations shall be furnished to the using agency on each system. Williams & Hazen formula to be used with C = 120.

(10) Weight switch to be installed on valve so that conveyor doors of that room shall close when the valve trips.

(11) All fire protection systems located in areas monitored by television in control room, shall be capable of being manually actuated from the control room.

(12) Fire protection systems shall comply with all mandatory requirements as set forth by the National Fire Protection Association, unless modified by the above requirements.

(13) When a system trips, the fire doors of the room will close, and the nozzles at the doors in the adjoining rooms shall be activated.

(14) O.S. & Y. valves shall be controlled from outside the room.

(15) Water mains for fire protection shall be looped.

r. Safety Features:

For nature, type, quantity and location of explosives, see SK-SAAP 3051 and SK-SAAP 3052. Walls that are not common to the equipment room shall be constructed so that they will serve as blow out panels.

s. Special Features:

Radio frequency shielding shall be provided for walls, ceiling, floors, doors and blow out panels in the heat room and the annealing room. Shielding shall be sufficient to meet the requirements of Part 18 of the FCC Regulations.

t. Power:

Primary power feeder to each substation will be 12470 volts, lighting feeder will be 4160 volts, commencing at the aerial to the east underground structure of the Main Switch Yard (Account No. 154-4) travel east approximately 3000 feet then south approximately 7000 feet on open copper wire, flat pole line construction and terminate at location of the last substation. Primary and lighting wiring will be large enough to accommodate a total capacity of four (4) substations each sized at 2250 KVA. Tie-in of feeders will be accomplished by the Operating Contractor on the weekend after a minimum of two full weeks notice from the Contractor. Each substation will be located at least 50 feet from the building and the secondary will be underground, encased in red concrete from the substation to the main switch gear located in the equipment room of the complex. Control circuits will be underground encased in red concrete from the equipment room of the complex to the control building. Each line of the complex will require 1000 amperes of 440 volt power for process equipment operation. Each line will have a circuit breaker in the substation. Equipment in process rooms will be Class I, Group D, Class II, Groups E, F & G. General purpose equipment will be used in nonhazardous areas. Switch gear shall be provided for power and lighting to each processing line, control room, and equipment room. Control voltage to be obtained from the power source by use of transformers. Power and control to have one common cutoff point (circuit breaker) per unit of equipment. Overhead lines shall not be installed with 50 feet of any explosive building.

u. Lighting:

Interior lighting shall be fluorescent fixtures, supplying 100 footcandles of illumination where TV cameras are located. All other interior areas of the complex shall have 30 footcandles of illumination. The control rooms shall have a minimum of 50 footcandles illumination. Fixtures in hazardous areas shall be approved for Class I, Group D and Class II, Groups E, F & G. A low current fuse of 1.5 amps or less shall be installed in each line wire to protect the ballast. These fuses shall be located within the fixture housing when the ballast incorporates two (2) one-shot type internal protective devices. Fuses located in the ballast compartment shall be mounted in a holder which totally encloses the fuse so that on removal the line connection is not accessible. Fixtures shall not be mounted directly over open process equipment and shall be located as remote as practical from the hazard involved. All other fixtures shall be general purpose. Exterior area lighting shall be a minimum of 5 footcandles. Rechargeable battery operated emergency lights shall be installed in the control rooms and equipment rooms and shall be capable of operating a minimum of 30 minutes.

v. Receptacles:

A 110 volt A.C. single phase three prong twist lock receptacle shall be provided adjacent to the doors to the process rooms on the outside of the vent walls. Outlets shall be provided in the control rooms and equipment rooms to accommodate maintenance requirements.

w. Telephone, Intercom, TV:

Closed circuit TV cameras to be located as shown on SK-SAAP 3114. Conduit for cameras shown by dashed lines are to be installed on Phase I for utilization in Phase II & III. Monitors shall be located in the control rooms. Cameras shall be approved to meet Class I, Group D and Class II, Groups E, F & G. Monitors shall be general purpose type. An intercom system shall be installed for each process line between the control room and each process room and between the equipment room and each process room and the control room. The system shall be multi-channel page and reply system with paging speakers and handset station for communication to be approved for Class I, Group D and Class II, Groups E, F & G in hazardous rooms. Amplifiers and power supplies and relays may be located in the equipment room and be for general purpose. Provide a spare underground conduit for telephone installation.

x. Alarms Systems-Intrusion:

Nutating red lights shall be located on the roof at each end and in the middle of each process line. The lights shall be located such that they are readily visible when the process line is in operation.

y. Grounding:

(1) A comprehensive grounding system shall be provided for each operating building which will interconnect all conductive facility items and equipment not specifically designed to carry electric current. In addition, neutrals of electrical systems will be grounded when floating neutrals are not a necessity.
(2) The ground connection to earth shall be made by connecting to one of the following; driven ground rods, counterpoise systems or underground service water lines. If two or more of the above exist, they shall be tied together. (Refer to National Electric Code, Article 250 for requirements and details.)
(3) Materials installed specifically as grounding conductors and connections to equipment should not be painted or coated in any way.
(4) Interior exposed ground wires in buildings shall be not less than No. 4 bare copper wire and shall be free of splices or joints as much as possible. Use electrically equivalent aluminum wire if copper is not compatible with materials being processed.
(5) Equipment grounds shall be not less than No. 12 copper wire and should be free of splices or joints. This wire may be either bare or insulated dependent upon application.
(6) All steel columns, beams and trusses shall have electrical continuity.

The structure should be connected to the same grounding system at not less than two places.

(7) All underground connections shall be made by brazing or by thermit welding (Cadweld or Thermoweld process). Connections to ground rods or secondary cables shall be electrically continuous.

(8) All unwelded connections shall be accessible for visual inspection.

Testing and Inspection

(a) All systems shall be tested for resistance and continuity prior to use.

(b) Equipment grounds shall measure a maximum resistance of 25 ohms to earth. When lightning protection is also required, the maximum resistance to earth shall be 10 ohms.

z. Lightning Protection:

All buildings shall be protected against lightning. The system used may be either integral, mast, or cone system, whichever is the most economical for the particular application. Static wires, shields, or other such protective means shall be installed for all distribution systems above 600 volts. Lightning arrestors shall be installed on the primary of all outside transformers. All must be designed in accordance with requirements of AMC-395-224.

aa. Description of Process Controls:

The start button is pushed and R is energized. R is held energized through RA and R2A contacts. R2A contacts are closed by R2 being energized through receiving dock door switch R5A, normal closed R3A and normal closed TD3A. R5A contacts close as R5 is energized through LRA and TD3B closed contacts (TD3B contacts close 100 m.s. after applying power and will open at preset time after power is removed). RB contacts close energizing R1 and green "on" light, through normal closed "stop" button. R1A contacts close forming a hold circuit for R1. R1B contacts close applying power to process control circuit. RC contacts are used to check LR for proper position. If LR is not in proper position then LRB contacts are closed and LR is pulsed. LR is a single coil impulse type relay. RD contacts close lighting the green loading light located at the receiving dock door. Upon seeing the "load" light, the operator opens the dock door which opens the door switch and deenergizes R2 opening R2D and R2A contacts stopping conveyor #1 and deenergizing R. The operator now places four tubs of paste on #1 conveyor as close together as possible. He now shuts the dock door closing the door switch which allows conveyor #1 to start running by again energizing R2 closing R2D contacts. Product moves to fire door #1 where the first tub closes FD1 energizing R4 and fire door solenoid valve SV1, opening fire door #1. R4A contacts closed forming a holding circuit for R4 and SV1 through previous closed R2B contacts. The tubs now move through fire door #1 onto conveyor #2 which is already running through closed contacts R5C. R5 was energized through LBA contacts and TD3B contacts when power was first applied. The tubs move up conveyor #2 till all tubs have cleared fire door #1 then FD1B closes energizing R3. R3A contacts open allowing R2 to deenergize stopping conveyor #1. The tubs move on up conveyor #2 until the first tub is in the dump position closing the tub "dump" switch pulsing LR. LBA contacts open deenergizing R5. R5C contacts open stopping conveyor #2. R5B contacts go to the normal closed position and if the level probe LP located in the delumper hopper, is wanting paste, then the tub dump solenoid SV2 is energized causing the tub to dump into the transfer hopper, also TD5 is energized. TD5 times a preset time (long enough to allow tub to empty) and opens TD5A contacts which deenergizes SV2 allowing the tub to drop again pulsing LR causing LBA contacts to close again energizing R5 opening R5B closing R5C starting conveyor #2 and closing R5D energizing R6. R6A starts conveyor #3 and R6B starts conveyor #4. The next tub on conveyor #2 pushes the empty tub off dump position to conveyor #3 to be taken away. As the next tub hits dump switch the cycle again repeats (conveyors #2, #3 and #4 start and stop together). As the fourth tub pushes the third tub onto conveyor #3, the first tub triggers FD2A and energizes R7 through normal closed R8B contacts. R7A contacts close forming a holding circuit for R6. R6B causes conveyor #3 to run and R6C contacts close causing conveyor #4 to run. R6A closing readies fire door #2 circuit. Conveyor #3 runs the three empty tubs (tub 4 is emptying) down conveyor #3 to FD2B which closing energizes fire door #2 solenoid SV4 opening fire door #2. The tubs pass through and onto conveyor #4. The tubs proceed down conveyor #4 to FD2C closing it and energizing R8 and green "load" light. R8A opens causing conveyors #3 and #4 to stop. The loading operator now has a green "load" light so he opens the door, removes the empty tubs and then reloads conveyor #1 with four full tubs. The removal of the empty tubs turns out green light until door is closed and cycle is again repeated. With the process on supplying power and assuming all interlocks are in proper position. Solenoids 17 and 18 energize opening guillotine doors 11 and 12. It is also assumed that conveyors #13, #14, #15, #17, #18, #19 and #20 are running. With conveyor #14 running, RG4 closes energizing R23 and the "Dielectric On" light. R23A contacts close. R23B contacts close turning on the dielectric heater. R23C contacts open turning off the conveyor #14 not running alarm.

(

PT01 times on energizing R13 and the amber "Batch Weigh" light through R23A, R15A and R14A contacts. R13A contacts close and solenoid SV6 energized opening fire door #4. R13B, C, D, E and F contacts close putting conveyors #5, #6, #7, #8 and #9 into weigh speed. R13G contacts close starting the delumper. Product starts moving on conveyor #5 on through fire door #4, into the delumper. Product goes through the delumper onto conveyor #6 under the moisture sensor. The moisture sensor monitors the moisture content of product passing under it. The moisture sensor output is amplified then fed into a millivolt to current converter. The converter output is fed into the weigh controller set point input. The set point of the controller now will vary with product moisture content. The set point will determine at what weights WAA and WAS contacts close.

The product then goes onto conveyors #7 and #8 and under the metal detector. If metal is detected in the product as it passes under the metal detector, contacts MD close. MD contacts stay closed until metal detector is reset. R12 and red "Metal Reject" light are energized through closed MD contacts. R12A contacts close energizing TD1 and TD2 time delay relays. R12B contacts close setting up metal removal arm circuit. R12C contacts close energizing the metal alarm. TD2 times out a short time after metal detection. TD2A contacts close energizing the metal detection arm solenoid SV5. Product is now rejected for a length of time that allows metal contaminated powder to be rejected. TD1 now times out causing TD1A contacts to close resetting the metal detector which opens MD contacts letting R12 deenergize. R12A, B and C open resetting the metal detector circuit.

After the product has passed under the metal detector, it then goes onto the weighing conveyor, conveyor #9. The weighing transducer translates product weight into a millivolt to current converter into a weight controller recorder. The weight controller output is fed into current sensitive relays WAA and WAS. These relays are adjustable and are set to operate as the output of the weight controller approaches (WAA) weight and at (WAS) desired weight. As the product weight on conveyor #9 approaches the desired weight, contacts close assuring R14 staying energized. R14A contacts open deenergizing R13 and the amber "Batch Weigh" light. R13B, C, D, E and F contacts open taking conveyors #5, #6, #7, #8 and #9 out of weight speed. R14D, E, F, G and H contacts close putting conveyors #5, #6, #7, #8 and #9 into trim speed. R13A contacts open but R14C contacts close keeping fire door #4 open. R13G contacts open but R14J contacts close keeping the delumper running. The product continues to dribble onto #9 weighing conveyor, until the desired weight is reached. The controller now causes contacts WAS to close energizing R15 and the green

"Batch Transfer" light. R15A contacts open deenergizing R14 and the blue "Batch Trim" light. R14A closes and R14B opens readying R13 and R14 for next cycle. R14C opening causes SV6 to deenergize closing fire door #1. R14D, E, F and G open leaving conveyors #5, #6, #7 and #8 disconnected and they stop. R14H contacts open taking conveyor #9 out of trim speed and R15C contacts close placing conveyor #9 into transfer speed. R14J opens stopping the delumper. R15B contacts close energizing solenoids SV3 and SV4 opening fire doors #5 and #6. Product moves on conveyor #9 through fire door #5 onto conveyor #10 to #11 to #12 through fire door #6 and through the dielectric heater. PT01 times off at 10 seconds from start.

PT02 times on but it serves no function except the filling of a time gap. PT02 times off at 22 seconds and PT03 times on. PT03 times off and PT04 times on at 24 seconds. PT04 times off and PT05 times on at 26 seconds. PT05 times off at 28 seconds and PT06 times on. PT06 times off at 32 seconds and PT07 times on. PT03 through PT06 time will be treated with later.

PT07 times on at 32 seconds energizing R22 and fire door #7 solenoid SV14 opening fire door #7. R22 will be treated with later. Product empties through fire door #7 into a hopper closed by fire door #8. PT07 times off and PT08 times on at 59 seconds. Fire door #7 closes as PT07 times off and fire door #8 opens as PT08 times on by energizing solenoid SV15.

Fire door #8 opening dumps product into charging bucket. PT09 times on as PT08 times off at 64 seconds. PT08 timing off closes fire door #8. PT09 timing on energizes R16 and bucket up solenoid SV9. R16A contacts close creating a hold circuit for R16 and SV9 through normal closed R22A contacts. The bucket starts to raise. It continues to a point just prior to dumping. A limit switch BHLS closes energizing the bucket hold solenoid SV10 through normal closed contacts R17A. The bucket will hold until R17A contacts open. PT09 times off at 80 seconds and cycle returns to PT01 time. PT01 and PT02 time through and PT03 again times on. PT03 energized #2 calender #1 doctor blade solenoid SV11 and through normal closed contacts R20A, SV12 solenoid opens fire door #9. R18A closes holding SV12 and R18 energized through normal closed contacts R22C. R18C closes putting conveyor #16 into entrance speed. PT03 times off and PT04 times on energizing calender #1, #4 doctor blade solenoid SV13 and through normal closed R21A energizes R19. R19A close energizing R17. R19B contacts open deenergizing SV10 allowing the bucket to proceed to dump. R17B contacts hold R17 energized through R22B contacts. PT04 times off and PT05 times on energizing R20. R20A contacts open deenergizing #2 doctor blade solenoid SV11. PT05 times off and PT06 times on energizing R21. R21A contacts open calender #1, #4 doctor blade solenoid SV13. PT06 times off and PT07 times on energizing R22 and SV14 (fire door #3). SV14 was discussed previously. R22A, B, C and D contacts open resetting bucket and doctor blade circuits and letting the bucket lower. R22E contacts close energizing fire door #10 solenoid SV16 through normal closed SES. R22F contacts close putting conveyor #16 into transfer speed until the edge detector on conveyor #17 senses the product as it is about to enter calender #2. SES (edge sensor) contacts open closing fire door #10 by deenergizing SV16. PT07 timing off stops conveyor #16.

Product now enters the calender #2 passes through onto conveyor #18 out through guillotine door 11 onto conveyor #19 through the cooling tank, through guillotine door 12 onto conveyor #20 into the winder. The cycle keeps repeating.

The winder drops a completed carpet roll onto conveyor #21. The carpet roll moves down conveyor #21 until it closes FD3A energizing fire door #13 solenoid SV19 and R27. Fire door #13 opens R27A contacts close holding R27 and SV19 energized keeping fire door #13 open until the carpet roll opens FD3B on conveyor #22, deenergizing SV19 and R27 allowing fire door #13 to close until next carpet roll arrives. The carpet roll goes on down conveyor #22 until it closes FD4A energizing fire door #14 solenoid SV20 and R28. SV20 causes fire door #14 to open and R27A contacts form a holding circuit for R27 and SV20 which keeps fire door #14 open until carpet roll passes onto conveyor #23 where it opens FD4B deenergizing SV20 and R28 letting fire door #14 close until the next carpet roll.

T3 and TD4 are delay on release types. If external interlock circuit is opened then these relays will time off at a set time later. This allows any product under fire doors #1, #2, or #3 to clear before doors close by keeping conveyors on a short time after interlocks drop out.

bb. Environmental Control:

The control houses shall be air-conditioned for the electronic process control equipment. Temperature range shall be $73^{\circ} \pm 2^{\circ}$F.

Heating shall be forced-air nonrecirculated steam heat in hazardous areas. In nonhazardous areas the heating system shall be general purpose. Design temperatures for heating shall be 0° outside, 75°F inside.

Fans shall be of nonsparking material.

A heat actuated fire damper shall be installed in each duct.

Heating and air-conditioning equipment shall be located outside the building barricade with air being supplied via ductwork.

Fan belts shall be of electrically conductive rubber.

Axial fans shall not be used.

Fan motors shall be located external to the duct.

Ducts shall be constructed of electrically conductive material designed to provide electrical continuity.

Ducts shall be grounded.

Ducts shall be designed and installed in such a manner which will minimize the accumulation of dust.

All ducts shall have adequate inspection and cleanout ports.

Only one side of the building may be served by one heating and ventilating system.

Blow-out panels shall be installed in each duct between the operating building and the fire damper.

The heat-actuated fire damper shall actuate at a temperature of approximately 160°F.

The fire dampers shall be provided with locking devices to hold the dampers in the closed position after actuation.

Fans and blowers shall be interlocked with the sprinkler system, thereby stopping the air supply in the event the sprinklers are activated. Each side of the building is to operate separately.

Pneumatic controls to be used.

Ventilation shall be forced-air nonrecirculated with a minimum of 8 changes per hour and comply with the requirements for heating.

cc. Plumbing Fixtures:

Male and female toilet facilities shall be provided in each control room. Each control room will have three (3) male and three (3) female operators per shift.

dd. Utilities:

Existing water and steam lines are shown on Drawing SK-SAAP 3111. Individual air compressors for each process line shall be furnished as shown on Drawing SK-SAAP 3114. No natural gas is required. Steam lines, both inside and outside, shall be insulated. Outside steam lines shall be aluminum covered.

ee. Doors & Hardware:

Unless otherwise shown on the drawings all doors shall be 3'-0" x 7'-0" size. All doors and openings shall be constructed in accordance to NFPA phamplet. All building hardware shall be industrial grade, non-ferrous, and grounded. The overhead door at the loading dock shall be air operated with steel tracks and nonferrous hardware.

ff. General:

(1) The construction contractor shall comply with all plant rules and regulations during the construction period.

(2) Drawings and Data

(a) Preliminary Drawings

It is requested that two (2) copies each of single line preliminary drawings and outline specifications be submitted through the COR to the Operating Contractor for review and approval of general design and arrangement and compliance with specific design criteria requirements.

(b) Final Drawings

Two (2) copies each of final drawings and specifications will also be submitted through the COR to the Operating Contractor for review and approval of general design and arrangement and compliance with specific design criteria requirements.

(3) Drawings and Data to be Furnished to the Operating Contractor

The Operating Contractor shall be furnished four (4) copies of spare parts lists for each item (where applicable) within two (2) months after the awarding of each purchase order. This information shall contain the name of each item on the purchase order, purchase order number, model number and/or serial number, etc., and a list of recommended spare parts with catalog, part or piece number for the spare part.

Upon completion of the work, the Operating Contractor shall be furnished with the following:

(a) Four (4) copies of certified drawings and specifications or one (1) copy of certified reproducible drawings on all equipment installed, such as, motors, pumps, machinery special valves, etc.
(b) Reproducible drawings on all buildings or construction in an "as-built" status.
(c) Four (4) copies each of purchase orders on all purchases of equipment.
(d) Four (4) copies each of the installation, operation, maintenance repair and adjustment instructions of equipment.
(e) Four (4) copies of lubrication specifications, schedules and instructions.
(f) Four (4) copies of flow diagrams, calculations, and all other specific data necessary for permanent records concerning the equipment and/or machinery.
(g) Original drawing or one reproducible copy of any shop drawing that shows pertinent details of any construction not covered by other furnished drawings, e.g., sprinkler piping details.

APPENDIX

TASK A-1
PROGRAM PLAN FOR PE PROJECT 105

I. Purpose

In order to increase production efficiency of the next generation of Mechanized Roll Facilities small-scale studies of process variables and equipment will be accomplished. These studies will be made to evaluate the control of variables and process equipment by the use of the "latest state of the art" equipment. Engineering design, layout, equipment arrangement, design criteria and drawings necessary for a procurement package will be accomplished.

II. Scope

A. Investigation and tests will be accomplished in the following general areas:

Task A-1.0 Preparation of detail test plans for each task.

Task A-2.0 Feasibility study for the use of a continuous moisture analyzer for paste moisture and carpet roll moisture.

A-2.1 Description

The optimum production of a Mechanized Roll depends on the moisture level of the paste. At present a moisture analysis is made on each blend of paste before it is used. A continous analyzer would replace the moisture laboratory and provide a continuous input to a feed rate control. This test will determine the feasibility of this system of moisture control in the paste. A similar analyzer may be used to determine moisture in the carpet roll strip. In this application it could replace the moisture analysis being made by the powder laboratory and eliminate a 4-hour delay in getting the test results.

A-2.2 Elements of Task

A-2.2.1 Literature search

A-2.2.2 Screening of information and data

A-2.2.3 Contacting vendors of likely candidates for additional data

A-2.2.4 Testing of the most likely candidates with simulated paste mixtures

A-2.2.5 Procurement and testing of the best unit on the Mechanized Roll Production Unit (contingent on successful preliminary testing)

A-2.2.6 Reporting results in a final report

Task A-3.0 Testing of a temperature sensor for the pre-roll.

A-3.1 Description

The temperature of the propellant on the pre-roll is measured on the present unit with a radiation pyrometer. The sensor in use contains a thin gelating lens that is not moisture proof. A filter has been placed over the lens to protect it from moisture. But the use of the filter affects the sensitivity of the sensor to temperature changes in the 200° to 260°F range. The purpose of this test is to evaluate other radiation pyrometers to determine if they will be more suitable than the present unit for this use. The literature indicates there have been some recent improvements in the field of radiation pyrometry.

A-3.2 Elements of Task

A-3.2.1 Literature search

A-3.2.2 Screening of information and data

A-3.2.3 Contacting vendors of likely candidates for additional data

A-3.2.4 Testing of units in the laboratory under simulated operating conditions with inert material

A-3.2.5 Testing of the selected unit on the Mechanized Roll Production Unit (contingent on successful preliminary tests and a significant improvement over the present unit)

A-3.2.6 Reporting results in a final report

Task A-4.0 Feasibility of cooling the carpet strip with air in lieu of a water bath.

A-4.1 Description

The present Mechanized Roll Production Unit passes the carpet roll strip through a water bath and then between high-velocity air jets prior to being fed to the carpet roll winder. The best temperature for winding is between 80° and 90°F. Cooling the strip by air instead of water would prevent a residue of surface moisture which remains on the strip despite the air jets, and require an 8-hour delay of the carpet rolls in a heated bay before they are pressed in order to prevent voids from occurring in the pressed grains. This test will prove the feasibility of an air cooling system and provide data for designing such a system.

A-4.2 Elements of Task

A-4.2.1 <u>Laboratory Tests</u> - The available laboratory data on heat transfer and heat capacities of N-5 propellant will be used to estimate cooling requirements for the carpet roll strip. Then a test on cooling a small quantity of carpet roll strip from 150° to below 100°F will be conducted at varying air velocities and temperature differences. From this data an estimate for conditions required for a full scale test will be obtained.

A-4.2.2 <u>Full Scale Test</u> - (An approved test plan and safety review will be obtained prior to this test.) A stream of cooled, compressed air will be applied to the carpet roll strip as it emerges from the final roll bay. Temperatures before and after the application will be measured with surface thermometers. Conditions simulating air cooling applicable to a production design will be tried.

A-4.2.3 <u>Treatment of Data</u> - The data obtained in this test will be analyzed. If the feasibility of cooling the carpet roll strip with air is apparent, a design for a cooling compartment will be submitted.

A-4.2.4 <u>Final Report</u> - The results of this test will be presented in a final report.

Task A-5.0 Determination of the drying characteristics of a pre-roll sheet.

A-5.1 Description

In order to produce a pre-roll sheet with a desirable moisture content after one minute, fifteen seconds of differential rolling, two processes for drying the sheet are being considered. The first one is to feed the sheet on to an additional drying roll on the pre-roll mill. (This requires a 4-roll mill for the pre-roll instead of the 3-roll mill used in the present production unit.) The second process is to continue heating the pre-roll sheet in a hot-air dryer until the desired moisture level is obtained. This process has the advantage of using higher temperatures than those on the pre-roll without the risk of roll or knife fires which occur on the rolls.

A-5.2 Elements of Task

A-5.2.1 Laboratory Tests - The drying characteristics of the N-5 pre-roll sheet will be determined at temperatures up to 250°F.

A-5.2.2 Full Scale Air Drying Test - (An approved test plan and safety review will be obtained prior to this test.) If the laboratory data indicate favorable drying characteristics, a hot-air dryer will be installed in Roll House 7807-3, where a source of heated compressed air is already available. Differential sheets will be rolled to a moisture level of 1% to 1.5% and then passed through the dryer. Samples will be analyzed for moisture. The drying time and temperature will be varied.

A-5.2.3 Final Report.

Task A-6.0 Testing of improved materials for conveyor belts.

A-6.1 Description

The conveyor belts used in the weigh and heat room of the present installation are not fire resistant and absorb exudate from the paste which makes it even less fire resistant. Some improved materials are needed for these belts.

A-6.2 Elements of Task

A-6.2.1 Contacting Suppliers - The Technical Representatives of several vendors will be contacted to obtain data on available materials.

A-6.2.2 Laboratory Tests - The most likely candidate materials will be checked in the laboratory for compatibility with N-5 paste. Those that are compatible will be tested for NG absorption and heat resistance.

A-6.2.3 Full Scale Production Test - The material most likely to satisfy the requirements of the Mechanized Roll weigh and heat room will be purchased in a quantity sufficient for installing one belt in the present facility. If more than one material appears to be equivalent in the desired properties, more than one will be tested.

A-6.2.4 Preparation of a final report.

Task A-7.0 Investigation of increasing the capacity of the final roll.

A-7.1 Description

It is anticipated that the production rate of the pre-roll mill will be increased over the present unit by the use of a 4-roll pre-roll. This test is to determine if the final roll mill now in use is capable of handling the increased load. Increased roll speed would cause an increase in roll fires. The alternative would be to remove two strips at its present roll speed, thus doubling its feed rate and reducing the side strips that are fed back into the roll bite under present operating conditions. The purpose of this test is to determine if this approach is feasible and to determine other final roll requirements for an increased feed rate.

A-7.2 Elements of Task

A-7.2.1 Determine modifications necessary to the final roll mill.

A-7.2.2 Complete drawings of changes.

A-7.2.3 Complete work orders and procure materials.

A-7.2.4 Install modifications on final roll.

A-7.2.5 On test runs determine conditions and make changes as required.

A-7.2.6 Evaluate performance and determine effect on the product.

A-7.2.7 Report results in a final report.

B. Engineering studies, design, criteria and drawings will be accomplished in the following categories.

Task B-1 Design of conveyors.

Task B-2 Design of dividing wall opening fire doors.

Task B-3 Criteria for improved calenders.

Task B-4 Criteria for strip winder.

Task B-5 Design of dust collection systems.

Task B-6 Criteria for metal detector.

Task B-7 Criteria for dielectric heater.

Task B-8 Design of process controls.

Task B-9 Design of paste buggies.

Task B-10 Design criteria for facility.

B. K. Kedigh 12 September 1969

PE-105 MODERNIZATION OF MECHANIZED ROLL

EVALUATION OF MODEL 106 ANACON MOISTURE ANALYZER

12 September 1969 — Date | Bob K. Kedigh — Author

15 September 1969 — Date | L. A. Rasmussen — Approved

Date | Approved

SUNFLOWER ARMY AMMUNITION PLANT

TECHNICAL DEPARTMENT PROGRESS REPORT

B. K. Kedigh 12 September 1969

PE-105 - MODERNIZATION OF MECHANIZED ROLL

EVALUATION OF MODEL 106 ANACON MOISTURE ANALYZER

DIGEST

Objective

The objective of this study was to determine the accuracy of the Model 106 Anacon Moisture Analyzer for continuously monitoring moisture in N-5 paste. The results will establish the feasibility of using the analyzer for determining feed rates at the Mechanized Roll and charge weights at the conventional roll.

Summary and Conclusions

Calibration curves were prepared for the Anacon Moisture Analyzer because the instrument has no capability of internal calibration. Moisture values for N-5 paste were determined by two methods and the instruments meter readings referenced to the results from the two methods. The accuracy of the instrument was determined and environmental conditions which affect its accuracy and reproducibility were investigated.

The instrument produced values that were accurate to $\pm$ 1.16 percent of the true moisture, as determined by the Carbon Tetrachloride (CCl_4) Distillation Method, at the 95 confidence level. This accuracy was obtained when the instrument was set at a full scale moisture determining range of 0 - 15 percent. Adjusting the instrument moisture measuring range to 4 - 14 percent decreased the variation to ± 0.68 percent at the same confidence level.

The accuracy of the instrument was dependent on the accuracy of each test method used to determine true moisture and the selected instrument range setting. The instrument was not sensitive to small variations in environmental lighting, temperature and humidity. Varying the distance of the detector head from the sample surface resulted in a 3 percent change in the meter reading per inch of detector movement.

Recommendations

The following recommendations are included for using the Anacon Moisture Analyzer:

1. The instrument should not be used as a process or product control tool where accuracy of greater than ± 1.0 percent moisture is required.
2. Calibration curves must be prepared for each material to be monitored.
3. The instrument should be periodically checked for meter drift using a known material. The initial checks should be frequent and become less frequent as reliability is established.
4. Care should be taken to prevent dial setting changes or adjusting the detector head to sample distance once a calibration is obtained.
5. The instrument should not be used at temperatures above 100°F

without water cooling the detector head.

6. Prevent bright daylight sun radiation or incandescent lamp lighting from falling directly on the optics or on the material being measured, also prevent large amounts of dust from collecting on the glass window.

7. If the instrument is to be used with the detector head pressurized, it should be calibrated under similar conditions.

INTRODUCTION

The moisture content on N-5 paste presently used at the Mechanized Roll is determined from a sample taken at the Blender House. The time lag in shipment of the paste from the Blender to the Mechanized Roll causes a gain or loss in moisture from the initial moisture value given. The Anacon Moisture Analyzer would eliminate this time lag and continuously determine moisture content whereby adjustments in charge weights could be made immediately.

The moisture analyzer is a near infrared analyzer measuring water in solids and liquids. Water absorbs infrared energy and also reflects a certain amount. This reflectance is what is measured. The measuring wave length is usually 1.93 or 1.4 microns and the reference wave length is 1.7 or 1.2 microns.

This report summarizes the results obtained for calibrating the instrument against known moisture N-5 paste and also the limits of the instrument's accuracy.

EXPERIMENTAL

The problem encountered with the Anacon Moisture Analyzer was that the instrument has no capability of internal calibration. Recognizing this limitation, a series of known moisture standards were determined and referenced to the instruments meter reading.

The experiments were conducted using N-5 paste as a standardizing material. Analytically determined moistures were obtained for paste and the instrument was calibrated against the "true" moisture.

Three methods of determining true N-5 paste moisture were simultaneously performed in order to obtain the desired standardization curves. The first method used samples obtained from the Paste Air Dry (PAD) moisture laboratory. The moisture of these samples had been previously determined by a gravimetric measurement.[1] Instrument readings were obtained and referenced to the blower moisture (gravimetric) values. Samples were obtained that had moistures ranging from approximately 6 to 12 percent.

The second method of standardizing the instrument used a series of constant humidity environmental chambers. Samples of zero percent moisture N-5 paste were conditioned in environments of 98, 88, 65, and 0 relative humidity until moisture equilibrum was attained. The true moisture was determined by the weight changes in each sample and instrument readings were obtained.

The third method was similar to the first except that the initial moisture was determined by the Carbon Tetrachloride Distillation (CCl_4) Method.[2] The accuracy of the CCl_4 method was determined by comparing the results obtained when testing nitrocellulose to results obtained from the oven dried nitrocellulose method[3]. The N-5 paste moistures were then referenced to the instrument meter readings. Meter readings were obtained for paste samples from 0.76 to 14.26 percent moisture. Readings for the same paste samples were also obtained when the instruments sensitivity was increased.

The data from each method were statistically evaluated to determine limits of accuracy. The instrument's settings for all measurements obt d are shown in Table I.

TABLE I

INSTRUMENT DIAL SETTINGS

Instrument Dial	CCl_4 Moisture Range, Percent 0 - 15	CCl_4 Moisture Range, Percent 4 - 14	Blower Moisture Range, Percent 4 - 14
Sensitivity Range	X 2.5	X 5	X 5
Fine Sensitivity	100	100	100
Range Shift	≃ 6-87.0	≃ 6-42.0	≃ 6-40.0
Damping	0	0	0
Height of Detector Head From Sample (in.)	4¼	4¼	4¼

The effect of environmental conditions on the instrument's meter reading was determined. The conditions investigated included variations in room lighting, temperatures, height of detector head from material and material compaction. The instrument's measuring range and accuracy at various sensitivity settings were also determined.

DISCUSSION OF RESULTS

The results of the calibration of the moisture analyzer using N-5 paste are discussed in this section. True moistures were obtained by the blower (gravimetric method), carbon tetrachloride (CCl_4) distillation and by conditioning dry paste in a series of humidity environments.

Calibration of Instrument Using Blower Moisture Analysis as Reference

Samples of N-5 paste were obtained from the blower (PAD) lab that had moisture values from 6 to 12 percent. Meter readings were obtained for each sample (Table I) and plotted against the blower moisture values (Figure 1). An analysis of the data showed that a variation of ± 1.14 percent from the mean value could be expected. This variation was similar to the accuracy of the blower moisture method.

Calibration of Instrument Using Environmental Chambers to Produce Known Moisture Paste

No data were obtained from this study because N-5 paste exhibited a characteristic of not absorbing moisture from a high humidity environment. Dry paste exposed to 98 percent relative humidity reached equilibrium at approximately 1 percent moisture (10 day exposure). This moisture level was not satisfactory for the calibration. Therefore, the test approach was not pursued.

Calibration of Instrument Using Carbon Tetrachloride Distillation Moisture Analysis as Reference

The Carbon Tetrachloride (CCl_4) Distillation Method was determined to be accurate to ± 0.5 percent. This accuracy was determined by statistically comparing the CCl_4 values with oven dryed values obtained when analyzing nitrocellulose. It was assumed the same accuracy would be obtained for N-5 paste.

Meter readings were obtained for paste samples that ranged from 0 percent moisture to 15 percent (Table II). This range represented full scale on the meter. The instruments meter readings were plotted against the CCl_4 moisture (Figure 3) and showed a test variation of ± 1.16 percent from the mean value. The same samples were used to obtain meter readings when a more sensitive meter range (4-14 percent moisture) was used. Using the increased sensitivity range reduced the test variation to ± 0.68 percent (Table III and Figure 4).

Effect of Environmental Conditions on Analyzer

Some environmental conditions were found to slightly effect the instrument's accuracy, reproducibility and sensitivity.

Moderate illumination from 0 to 40 foot candles did not affect the meter reading but an illumination of 70 foot candles affected the meter reading by a decrease of 3 percent.

Temperatures of 75 to 95°F did not affect the instrument. The distance from the sensing head to the top of the 1 inch thick sample was maintained at $4\frac{1}{4}$ inches through the testing. However, it was determined that for every inch change in distance from the top of the sample to t'. :·nsing head there was a change of 3 percent on the meter reading.

It was determined that insufficient infrared rays were reflected to activate the Primac Sprinkler System in a building. Activation of the sprinkler system may occur if the infrared beam is aimed directly at a Primac sensor.

Sample compactness did not affect meter readings as long as the surface of the sample was fairly smooth and perpendicular to the infrared beam.

REFERENCES

1. Sunflower Army Ammunition Plant Procedure HD-5-3-3208, "Paste Moisture Lab.," Revision 5, June 12, 1969.

2. MIL-STD-286B, Military Standards Propellant, Solids, Sampling, Examination and Testing, Method 102.1.3, "Moisture (Distillation Method)," December 1, 1967.

3. Hercules Laboratory Manual, Method N 40a-3, "Nitrocellulose, Smokeless, Moisture (Oven)," September 26, 1940, Rev. 2, April 18, 1955.

TABLE II

PERCENT MOISTURE BY BLOWER METHOD VERSUS MOISTURE ANALYZER

Sample No.	Date	Meter Settings at X5 (Range Shift)	Meter Reading	% Moisture by Blower
L-710	7-16-69	6-40.0	40	8.0
L-710	7-17-69	6-40.3	30	7.1
L-710	7-17-69	6-40.2	51	8.9
L-712	7-18-69	6-41.0	47	8.2
L-712	7-18-69	6-40.8	88	13.1
7CD B1 41	7-22-69	6-40.3	50	8.0
7Cd B1 21	7-22-69	6-40.3	56	8.1
B1 44X 8AB	7-22-69	6-40.3	48	7.8
B1 25 7CD MR	7-22-69	6-40.3	57	8.3
B1 57 10CD	7-22-69	6-39.8	53	8.3
B1 56 10AB	7-22-69	6-39.8	58	8.8
B1 58 8CD	7-22-69	6-39.0	44	8.0
12 AB Reg.	7-23-69	6-40.1	56	8.5
8AB Sp. (Wet)	7-23-69	6-40.1	71	11.1
12AB Sp. (Side)	7-23-69	6-40.4	61	10.1
4AB	7-24-69	6-41.2	52	8.2
B1 87 4AB MR	7-24-69	6-41.2	42	6.3
B1 2X 5AB	7-24-69	6-41.2	61	9.0
B1 92X 4CD	7-24-69	6-40.3	50	7.6
B1 5X 5CD Reg.	7-24-69	6-40.3	66	10.1
MR 5CD	7-24-69	6-40.3	61	9.1

TABLE II contd.

PERCENT MOISTURE BY BLOWER METHOD VERSUS MOISTURE ANALYZER

Sample No.	Date	Meter Settings at X5 (Range Shift)	Meter Reading	% Moisture by Blower
22CD Init.	7-24-69	6-40.5	67	10.1
22AB	7-24-69	6-40.5	60	9.1
5AB Reg.	7-24-69	6-40.5	58	8.6
Special	7-24-69	6-40.5	74	11.5
L-715 I	7-25-69	6-40.1	76	11.0
L-715 II	7-25-69	6-40.1	70	9.6
L-715 III	7-25-69	6-40.1	77	10.4
L-716 I	7-28-69	6-41.0	69	8.9

TABLE III

PERCENT MOISTURE BY CCl_4 METHOD VERSUS MOISTURE ANALYZER

Sample No.	Date	Meter Settings at X2.5 (Range Shift)	Meter Reading	% Moisture by CCl_4
1	8-22-69	6-86.7	100.5	13.96
2	8-22-69	6-86.7	89	10.04
3	8-22-69	6-87.5	101	14.26
4	8-25-69	6-87.5	80	6.06
5	8-25-69	6-87.5	65	3.77
6	8-25-69	6-87.5	84	7.13
7	8-25-69	6-87.5	86	7.78
8	8-26-69	6-87.7	74	4.50
9	8-26-69	6-87.7	37	0.76
10	8-26-69	6-88.0	89	8.87
11	8-26-69	6-88.0	90	9.04
12	8-27-69	6-88.0	90	8.40
13	8-27-69	6-88.0	89	8.45
14	8-27-69	6-87.2	87	7.99
15	8-27-69	6-87.2	86	7.72

TABLE IV

PERCENT MOISTURE BY CCl_4 METHOD VERSUS MOISTURE ANALYZER

Sample No.	Date	Meter Settings at X5 (Range Shift)	Meter Reading	% Moisture by CCl_4
1	8-22-69	6-42.7	68	13.96
2	8-22-69	6-42.7	51	10.04
3	8-22-69	6-42-7	69	14.26
4	8-25-69	6-42.5	27	6.06
5	8-25-69	6-42.5	32	7.13
6	8-25-69	6-42.5	38	7.78
7	8-26-69	6-42.7	13	4.50
8	8-26-69	6-43.0	44	8.87
9	8-26-69	6-43.0	46	9.04
10	8-27-69	6-43.0	48	8.40
11	8-27-69	6-43.0	46	8.45
12	8-27-69	6-42.2	40	7.99
13	8-27-69	6-42.2	38	7.72

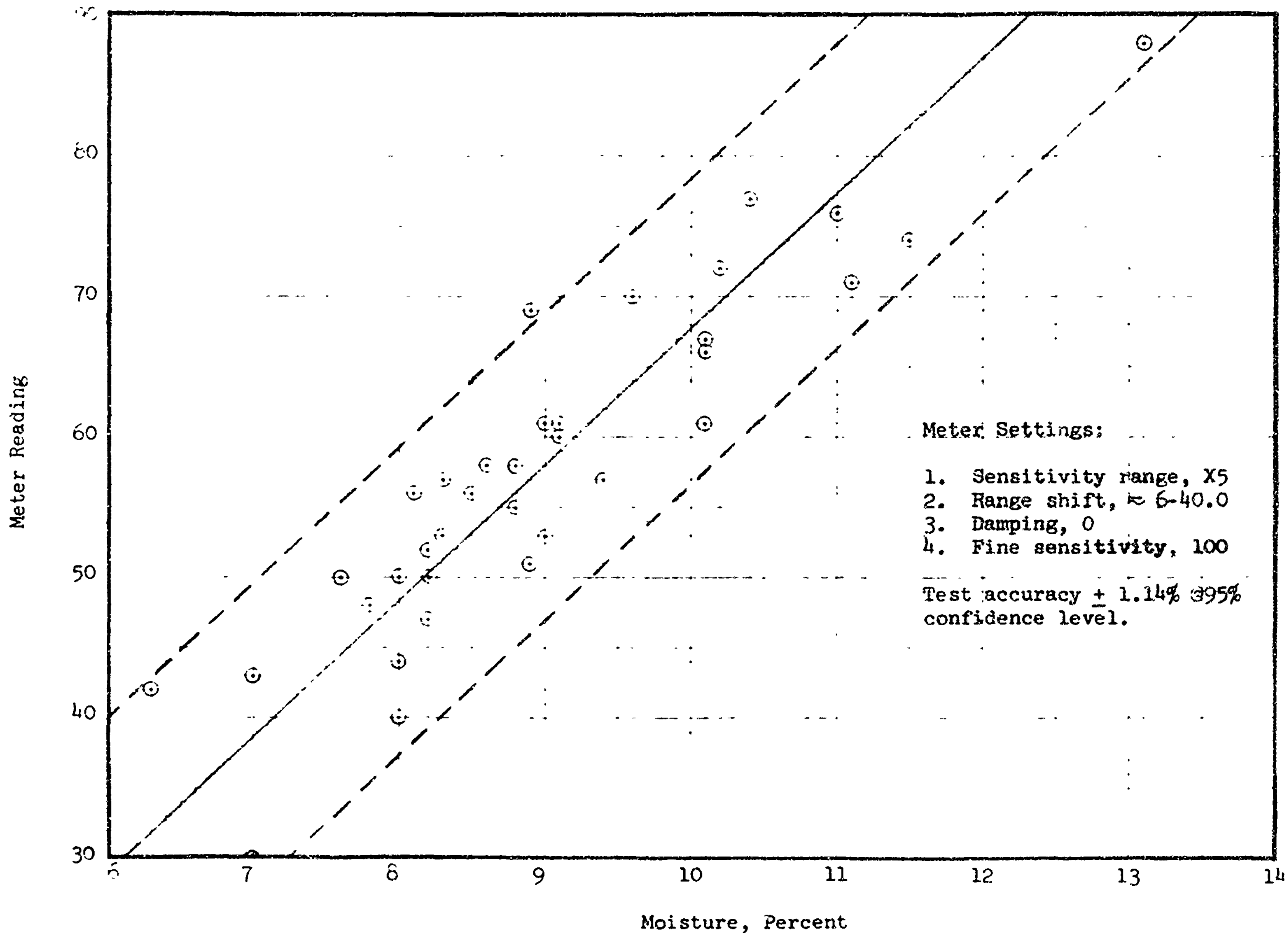


Figure 1, Meter Reading for Blower Moisture Determined N-5 Paste

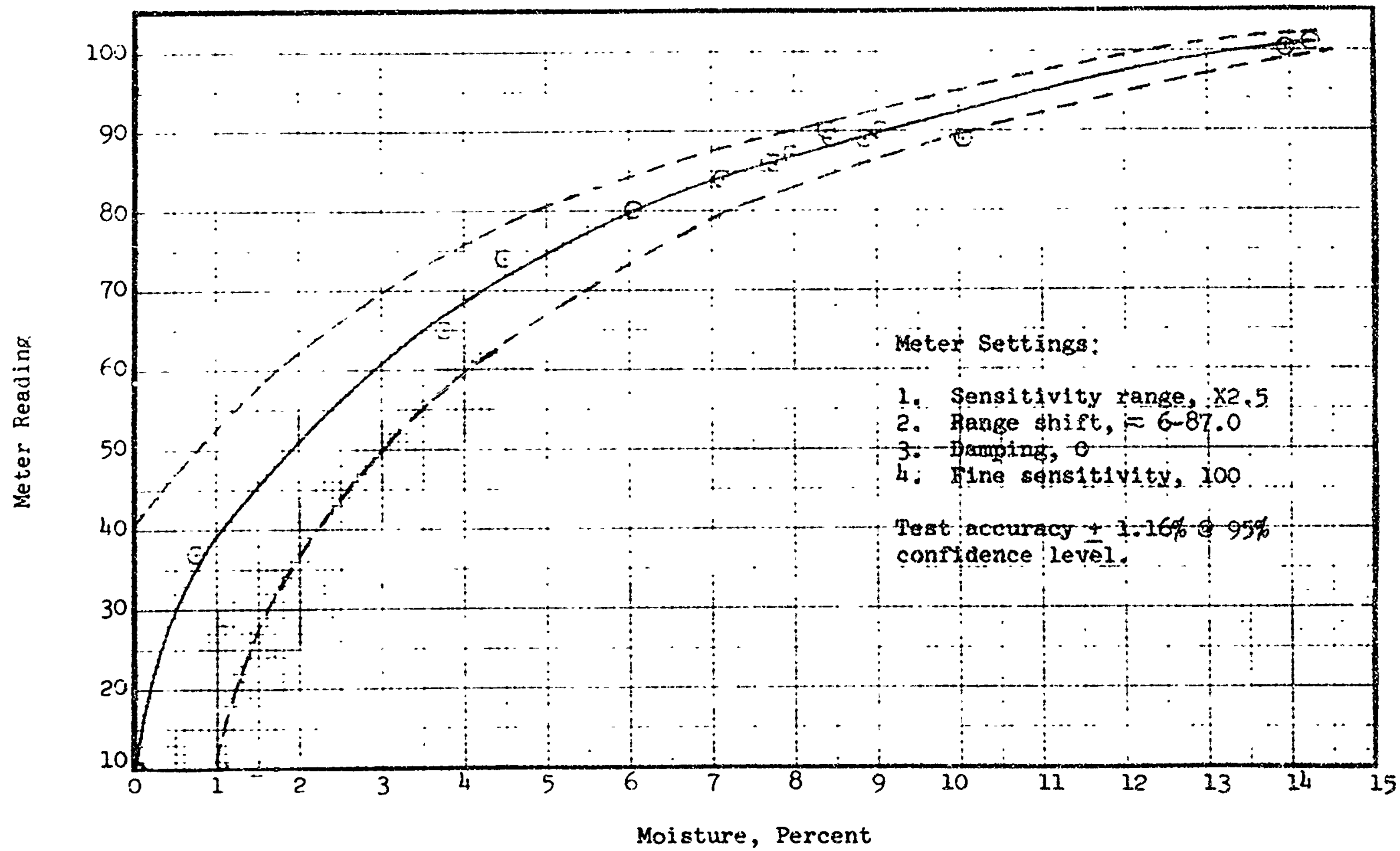


Figure 2, Meter Reading for CCl_4 Moisture Determined N-5 Paste

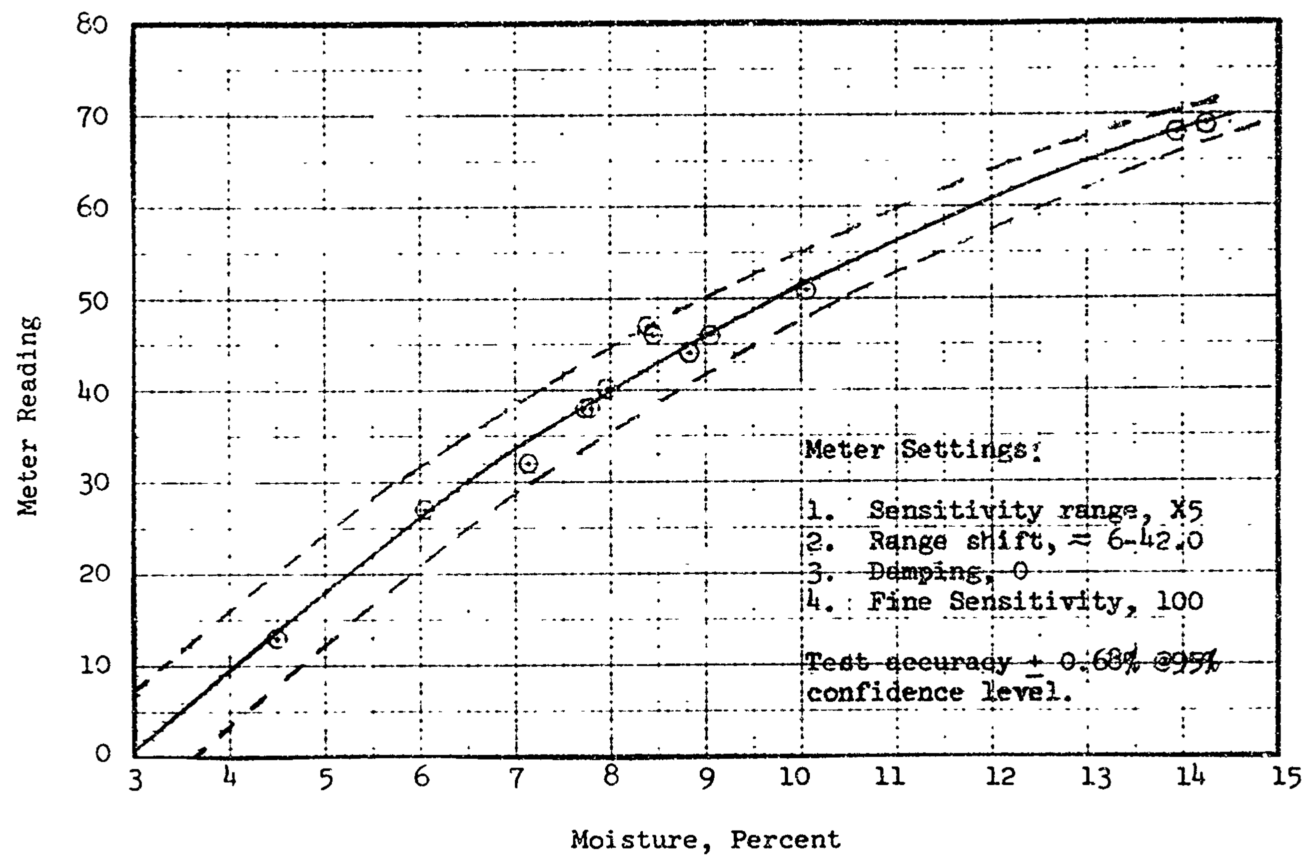


Figure 3, Meter Reading for CCl_4 Moisture Determined N-5 Paste unflower AAP Form SUN-309A (Rev. 1 68)

Memo-letter / HERCULES INCORPORATED

cc: J. S. Maurer
R. L. Frankenfield
F. L. Padan
W. L. Johnson
J. A. Montgomery
J. A. Rasmussen
file

DATE: Oct. 7, 1969

TO: J. S. Lampkin

FROM: B. K. Kedigh

SUBJECT: Evaluation of Anacon Moisture Analyzer - Pressurization of Sensing Head

Ref: Kedigh, B. K., "Evaluation of Model 106 Anacon Moisture Analyzer", 12 September 1969

Instrument meter readings were obtained for N-5 paste with a static pressure of 4 psig applied to the sensing head. Meter settings, distance of sensing head to sample, sample thickness, sample compactness, sample size and environmental conditions remained as previously reported.

The initial moisture content on each sample was determined by the Blower Moisture Method. The pressurized instrument readings (Table I and Figure 1) were somewhat lower than unpressurized values but within the reported accuracy limits.

TABLE I

PERCENT MOISTURE BY BLOWER METHOD VERSUS PRESSURIZED MOISTURE ANALYZER

Sample No.	Date	Meter Settings at x5 (Range Shift)	Meter Reading	% Moisture by Blower
1	9-26-69	6-42.5	45	8.0
2	9-26-69	6-42.5	46	6.3
3	9-26-69	6-42.5	45	8.7
4	9-26-69	6-42.5	50	9.1
5	9-29-69	6-43.7	33	7.6
6	9-29-69	6-43.7	42	7.8
7	9-29-69	6-43.7	20	6.1
8	9-30-69	6-44.0	36	7.4
9	9-30-69	6-44.0	36	6.9

B. K. Kedigh
B. K. Kedigh

bkk/mvr

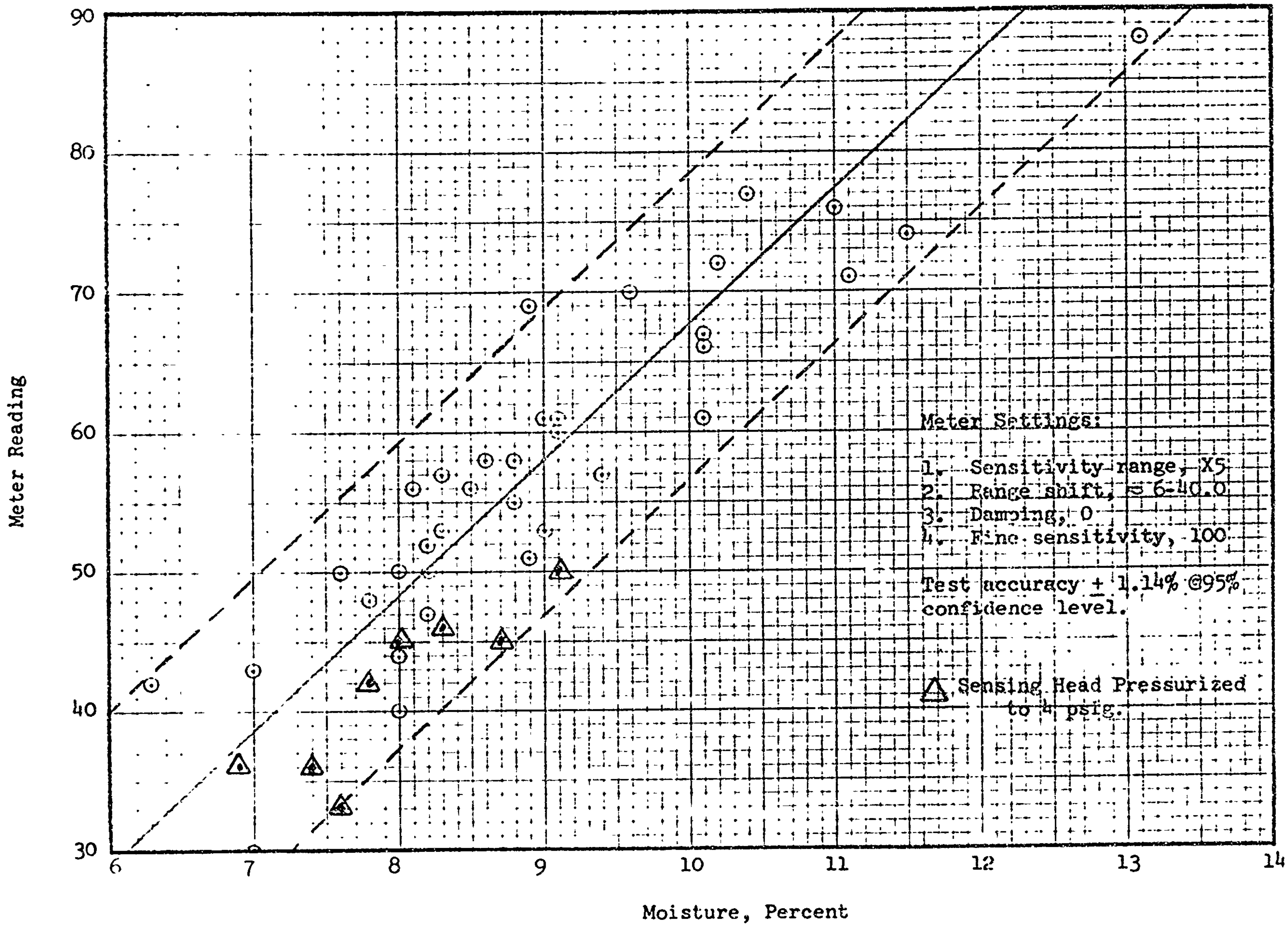


Figure 1, Meter Reading for Blower Moisture Determined N-5 Paste

Sunflower AAP Form SUN-309A (Rev. 1 68)

Memo-letter / HERCULES INCORPORATED

cc: J. S. Maurer
F. L. Padan
R. L. Frankenfield
C. N. Holliman
J. A. Rasmussen
file

DATE: June 6, 1969

TO: J. A. Montgomery

FROM: K. D. Cowan

SUBJECT: Calibration of Infrared Radiation Pyrometer, PE 105

The accuracy of the infrared radiation pyrometer was checked against a calibrated thermometer. The radiating body was Nujol which had been colored with 2-NDPA to approximately the color of N-5 propellant. The radiating surface was 4 inches in diameter and the infrared detecting head (lens) was placed 8 inches away from the radiating surface.

An infrared filter used in preliminary trials was found to affect the instruments sensitivity and since the filter was not going to be used at the mechanized roll house, it was not used in subsequent lab tests.

Tests were performed using the following lens materials: High density polyethylene, ethyl cellulose, cellulose acetate, lucite, surflex, "Baggies", 1.5 ml polyvinyl chloride, 7.5 ml polyvinyl chloride, and 4 ml polyethylene. High density polyethylene, ethyl cellulose, cellulose acetate, lucite, and surflex were eliminated from the study because they absorbed too much infrared radiation resulting in recorded temperatures 70 to 100 degrees below the actual temperature of the radiating body. The pyrometer could not be adjusted to correct for such large discrepancies. Polyvinyl chloride, "Baggies", and 4 ml polyethylene lens material gave associated readings and are compared on the following page.

The 4 ml polyethylene lens produced the most accurate measurement over a wide temperature range. This material was durable yet flexible enough to allow easy replacement. The pyrometer was originally equipped with a 4 ml polyethylene lens.

K. D. Cowan

K. D. Cowan

KDC/mvs

COMPARISON OF RECORDED PYROMETER TEMPERATURE WITH ACTUAL TEMPERATURE

THERMOMETER TEMPERATURE (°F)	PYROMETER TEMPERATURE (°F) LENS MATERIAL			
	4 ml POLYETHYLENE	"BAGGIE"	7.5 ml PVC	1.5 ml PVC
131			131	
153	152			
158	155			
162				166
167	168			
178	175			
185		193		
192				195
194		200		
198	197			
201	200	210	186	
203				207
204			194	
207	207			
212				214
226	226			
244	245			

K. D. Cowan

24 July 1969

PE-105 MODERNIZATION OF MECHANIZED ROLL

FEASIBILITY OF COOLING N-5 PROPELLANT CARPET STRIP WITH AIR

24 July 1969
Date

Author

24 July 1969
Date

Approved

SUNFLOWER ARMY AMMUNITION PLANT

TECHNICAL DEPARTMENT PROGRESS REPORT

K. D. Cowan 24 July 1969

PE 105—MODERNIZATION OF MECHANIZED ROLL

FEASIBILITY OF COOLING N-5 PROPELLANT CARPET STRIP WITH AIR

DIGEST

Objective

The objective of this study was to provide laboratory data for evaluating the efficiency of cooling N-5 propellant carpet strip with air. These data will be used for design and selection of cooling equipment to be used at the Mechanized Roll Operation.

Summary and Conclusions

Cooling curves (time versus temperature) for N-5 carpet sheet propellant were obtained using an air coolant passing over the propellant at flow rates of 0, 5, 10, 15, 20, 25 cfm at an air temperature of 82°F, and for flow rates of 5, 10, 15 cfm at air temperatures of 60°, 50°, and 20°F.

The cool down time of N-5 propellant was inversely proportional to the coolant air flow rate and proportional to air stream temperature. The greatest rate of heat loss (0.47 Btu/lb-sec.) was obtained using maximum air flow (15 cfm) and the lowest air temperature (20°F) obtainable in the laboratory. A cooling rate of 0.30 Btu/lb-sec. was obtained at 50°F air temperature and 15 cfm.

INTRODUCTION

Propellant (N-5) carpet strips manufactured at the Mechanized Roll Operation are presently cooled by passing the propellant through a water bath prior to forming the roll. Surface moisture remaining on carpet roll causes voids in the extruded grains. To prevent these defects, the carpet rolls are placed in a heated bay for 8 hours before pressing. Cooling the carpet roll strips by air would eliminate the problem of surface moisture, and the 8 hour delay before pressing.

The purpose of this work was to provide laboratory data for the cooling properties of N-5 carpet strip using air cooling methods.

EXPERIMENTAL

The apparatus used for this study is shown in Figures 1 through 4 and includes: a cooling chamber of 905 cu. in. internal volume; a rotometer with 50 cfm capacity; a pressure gage and regulator; an air line with 20 psi line pressure ($\frac{1}{2}$ in. ID nozzles); a six channel temperature recorder for monitoring the sample's interior and surface temperatures, and the incoming and outgoing air temperatures; and an oven for heating the specimens.

A copper cooling coil submerged in either a dry ice-acetone bath or a brine-ice bath was placed in the air line between the rotometer and cooling chamber to provide low temperature coolant air. The lowest air temperature obtained was 20°F. The maximum air flow rate obtained was 25 cfm without the cooling coil and 15 cfm with the coil inserted.

Carpet strip specimens of N-5 propellant with dimensions of 4-3/4 in. x 4-3/4 in. x 1/8 in. and of approximately 71 grams weight were used for this study. The specimens were supported in the center of the cooling chamber to allow air to circulate over their entire surface. The center of the specimen was approximately 7 inches from the air nozzles.

Each specimen, with attached thermocouples, was heated to an interior temperature of between 150° and 160°F and immediately transferred to the cooling chamber. An air stream of known temperature and flow rate (velocity) was turned onto the specimen. The air streams were directed to both top and bottom of the propellant at an angle of approximately 25 degrees from the horizontal. Temperature measurements were recorded on an automatic strip recorder. Propellant cooling curves were obtained using air flow rates of 0, 5, 10, 15, 20, 25 cfm at an air temperature of 82°F, and for air flow rates of 5, 10, 15 cfm at air temperatures of 60°, 50°, and 20°F. Air flow rates were also reported as velocities at the air line exits (nozzles).

DISCUSSION OF RESULTS

The time required to cool N-5 propellant was inversely proportional to the air flow rate and proportional to the temperature of the cooling air. A propellant sample allowed to cool in an ambient condition (82°F and 0 cfm air flow rate) required 486 seconds to cool from 150° to 90°F. The time for a similar propellant temperature change decreased with each increase in air flow rate. Using air at 82°F (Table 1 and Figure 5) the propellant specimen was cooled from 150° to 90°F in 410 seconds at an air flow rate of 5 cfm, in 216 seconds at 15 cfm, and in 160 seconds at 24 cfm. Reduction of the air temperature decreased the propellant cooling time at each flow rate. For an air temperature of 60°F (Table II and Figure 6), the desired drop in specimen temperature was attained in 172 seconds at 5 cfm, and in 104 seconds at 15 cfm. For an air temperature of 50°F (Table II and Figure 7), the desired drop in sample temperature was attained in 162 seconds at 5 cfm, and in 90 seconds at 15 cfm. For an air temperature of 20°F (Table III and Figure 8), the desired drop in sample temperature was attained in 98 seconds at 5 cfm, and in 58 seconds at 15 cfm.

Table IV shows the relative effectiveness of air temperature versus flow rate. Typical N-5 propellant was more rapidly cooled by lowering the air temperature than by increasing the flow rate. Air at a temperature of 50°F and flow rate of 15 cfm cooled the propellant as well as air at 20°F and a flow rate of 10 cfm.

Approximate cooling rates for N-5 propellant were calculated (Table V) for each flow rate and air temperatures assuming a uniform rate of heat loss. The optimum cooling rate was 0.47 Btu/lb-sec. and was obtained using 20°F air at a flow rate of 15 cfm. However, a good cooling rate of 0.30 Btu/lb-sec. was obtained using 50°F air at a flow of 15 cfm.

REFERENCES

1. Solid Propellant Manual (M-2), Chemical Propulsion Information Agency (CPIA), Unit No. 1121, N-5 Propellant, May, 1968

TABLE I

COOLING RATE OF N-5 CARPET ROLL USING AIR TEMPERATURE OF 82°F

TIME (sec)	PROPELLANT TEMPERATURE, °F											
	Flow Rate 25 cfm (153 f/s)		Flow Rate 20 cfm (122 f/s)		Flow Rate 15 cfm (91 f/s)		Flow Rate 10 cfm (61 f/s)		Flow Rate 5 cfm (30 f/s)		Flow Rate 0 cfm (0 f/s)	
	Surf	Int	Surf	Int	Surf	Int	Surf	Int	Surf	Int	Surf	Int
0	159	156.5	155	155	158	154	154	154	154	154	156	
18	152.5	148	154	153	156	150	150	150	150	149	148	159
36	110	128			120	134.5	122	136	128	138	138	154
54	101	115	108.5	126	110	125	112.5	128	120	131.5	131	149
72	97	108.5	102.5	118	105	118	108	121.5	115	126.5	126	145.5
90	94	104	98	111.5	100.5	112.5	103	116	111	122.5	123	141.5
108	92	99.5	95	106	98	108	100	112	107.5	119	120	138
126	90	96.5	92.5	102	98	104	98	108	105	116	119	134.5
144	88	93.5	90.5	98	93	100	95.5	105	102	113	116	131
162	87	92	89.5	95.5	91	98	94.5	102	100	110	112	128
180	86.5	90	88	93.5	90	95.5	92	99.5	98	108	109	124
198	86	89	87	91.5	88	93.5	90.5	97	96.5	106	107	122
216	85.5	88	86.5	90	87.5	91.5	90	95.5	95	104	105	119
234	85	87	86	89	86.5	90	89	94	94	102	103	116.5
252			85.5	88	86	88.5	88	93.5	93	100.5	102	114
270					85.5	88	87.5	91	91.5	99	100	112
288							87	90	91	97.5	99	110
306							86	89.5	90	96		
324									89.5	95	98	108
342									89	94	97	106.5
360									88	93	96	105
378									87	92	95.5	104
396									86.5	91	95	102
414									86	90.5	93.5	100
432									86	90	92	99
450									85.5	89.5	91.5	99.5
468									85.5	89	90.5	96
476											90	95
494											89	94
512											86.5	92.5
530											86	91
548											85.5	90
566											85	89.5
584											84.5	89

Test Conditions:

1. Gas flow rates measured by rotometer were not corrected to standard conditions. Variation was insignificant.

TABLE III

COOLING RATE OF N-5 CARPET ROLL USING AIR TEMPERATURE OF 20°F

PROPELLANT TEMPERATURE, °F

Time (sec)	Flow Rate 15 cfm (91 f/s)		Flow Rate 10 cfm (61 f/s)		Flow Rate 5 cfm (30 f/s)	
	Surface	Interior	Surface	Interior	Surface	Interior
0	151	150	156	154	156	151
42	69	102	81	114.5		117.5
60	63	89	72.5	103	80	106.5
78	61	80	67	94	74	97
96		77	63	86.5	69	90
114			60	80	65	84
132			58	76	61.5	79
150				74	59	74.5
168				72		72

TABLE IV

TIME REQUIRED TO COOL N-5 CARPET ROLL FROM 150°F TO 90°F AS A FUNCTION OF FLOW RATE AND AIR TEMPERATURE

Air Stream Temperature	Time Required for ΔT[b] (150°F to 90°F), sec.				
	Flow Rate 5 cfm (30 f/s)	Flow Rate 10 cfm (61 f/s)	Flow Rate 15 cfm (91 f/s)	Flow Rate 20 cfm (122 f/s)	Flow Rate 25 cfm (153 f/s)
82[a]	410	270	216	184	164
60	172	128	104		
50	162	118	90		
20	98	86	58		

Notes:

(a) At 0 cfm flow rate and 82°F, propellant sample required 486 seconds to cool from 150°F to 90°F.

(b) Temperature change from 150°F to 90°F.

TABLE V

APPROXIMATION OF COOLING RATES ASSUMING UNIFORM RATE OF HEAT LOSS FROM 150°F TO 90°F

Air Temperature, °F	Rate of Heat Loss, Btu/lb-sec				
	Flow Rate 25 cfm (153 f/s)	Flow Rate 20 cfm (122 f/s)	Flow Rate 15 cfm (91 f/s)	Flow Rate 10 cfm (61 f/s)	Flow Rate 5 cfm (30 f/s)
82	0.17	0.15	0.13	0.10	0.07
60			0.26	0.21	0.16
50			0.30	0.23	0.17
20			0.47	0.31	0.28

Test Conditions:

1. Heat capacity N-5 propellant, 0.45 Btu/lb-°F
2. Sample weight, 0.1562 lb (71 grams)
3. Rate of Heat Loss = $\frac{Cp \times \Delta T}{t}$ = Btu/lb-sec.

Where: Cp = Specific Heat of N-5 propellant in Btu/lb-°F

ΔT = Temperature Differential in °F

t = Time required for ΔT in sec.

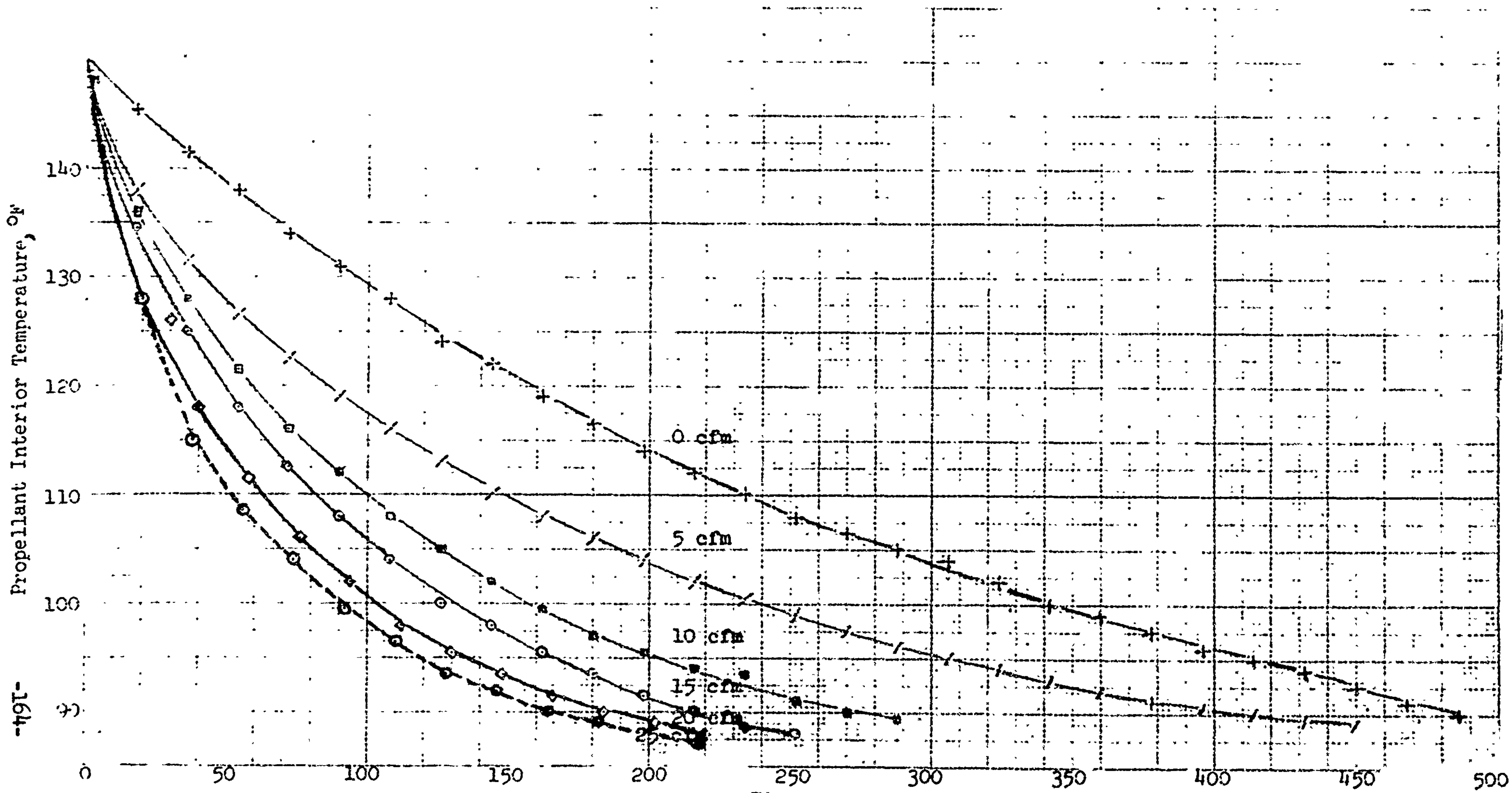


Figure 5, Cooling Curves of N-5 Carpet Strip for Coolant Air Temperature of 82°F

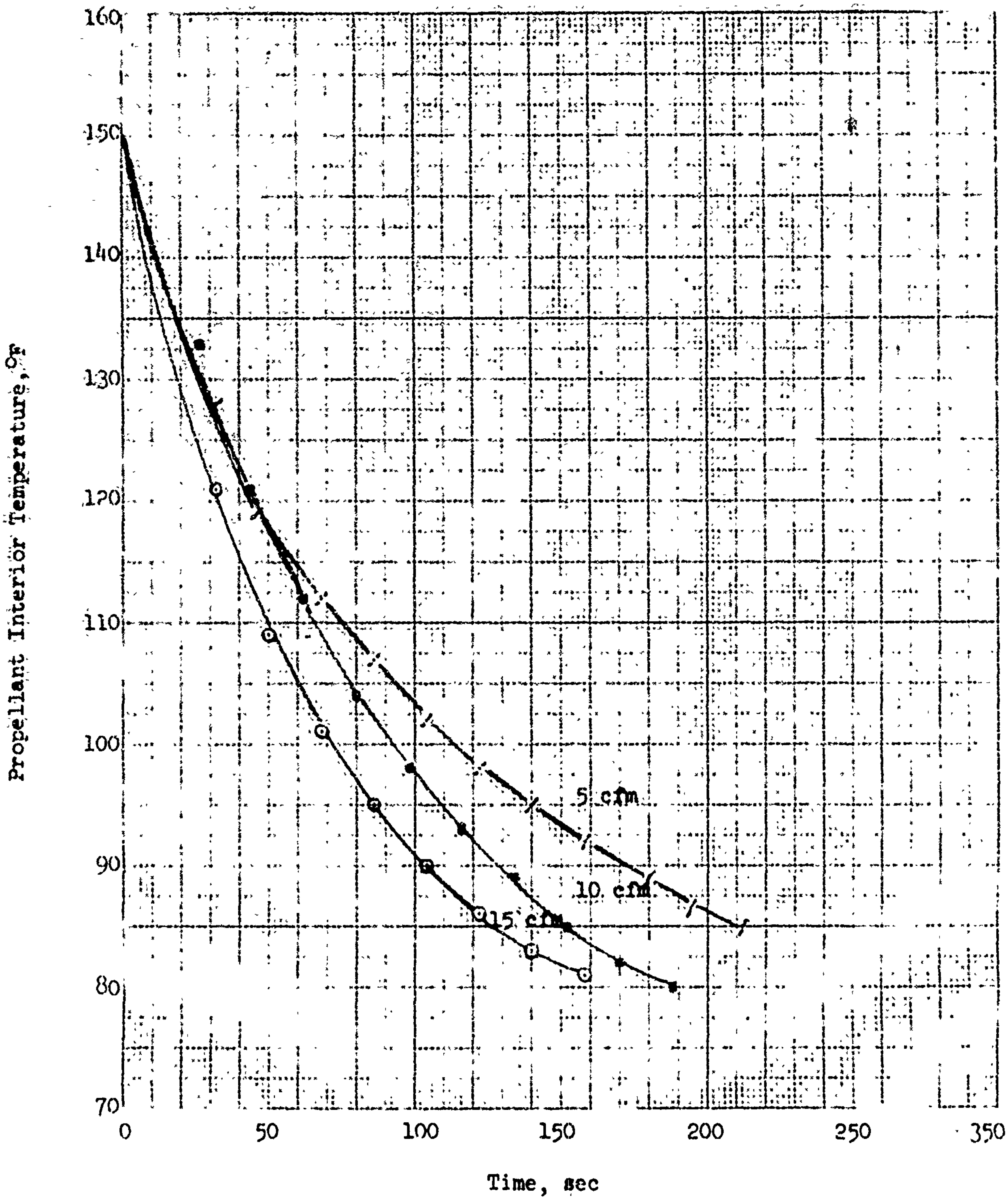


Figure 6, Cooling Curves of N-5 Carpet Strip for Coolant Air Temperature of 60°F

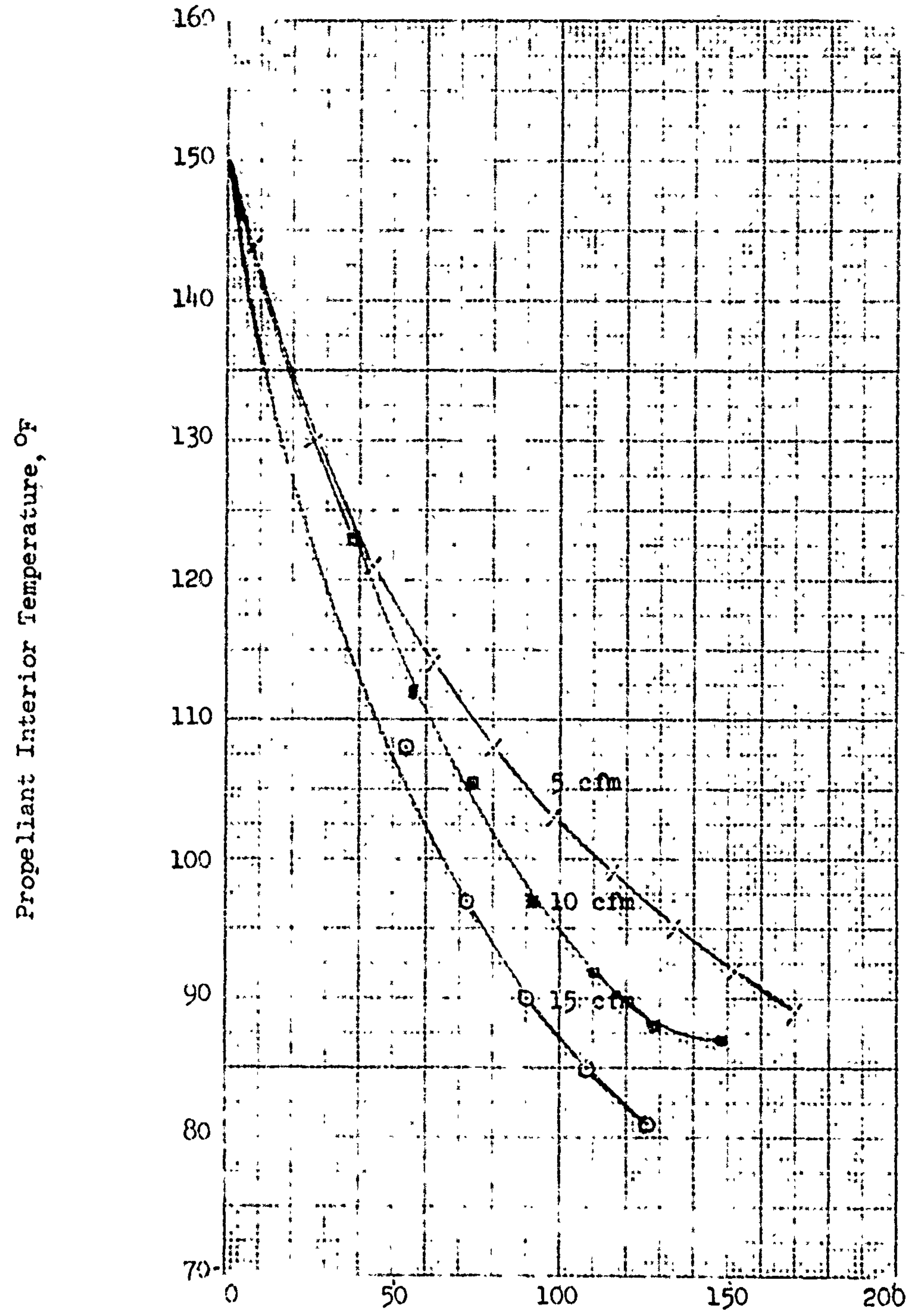


Figure 7, Cooling Curves for N-5 Carpet Strip for Coolant Air Temperature of 50°F

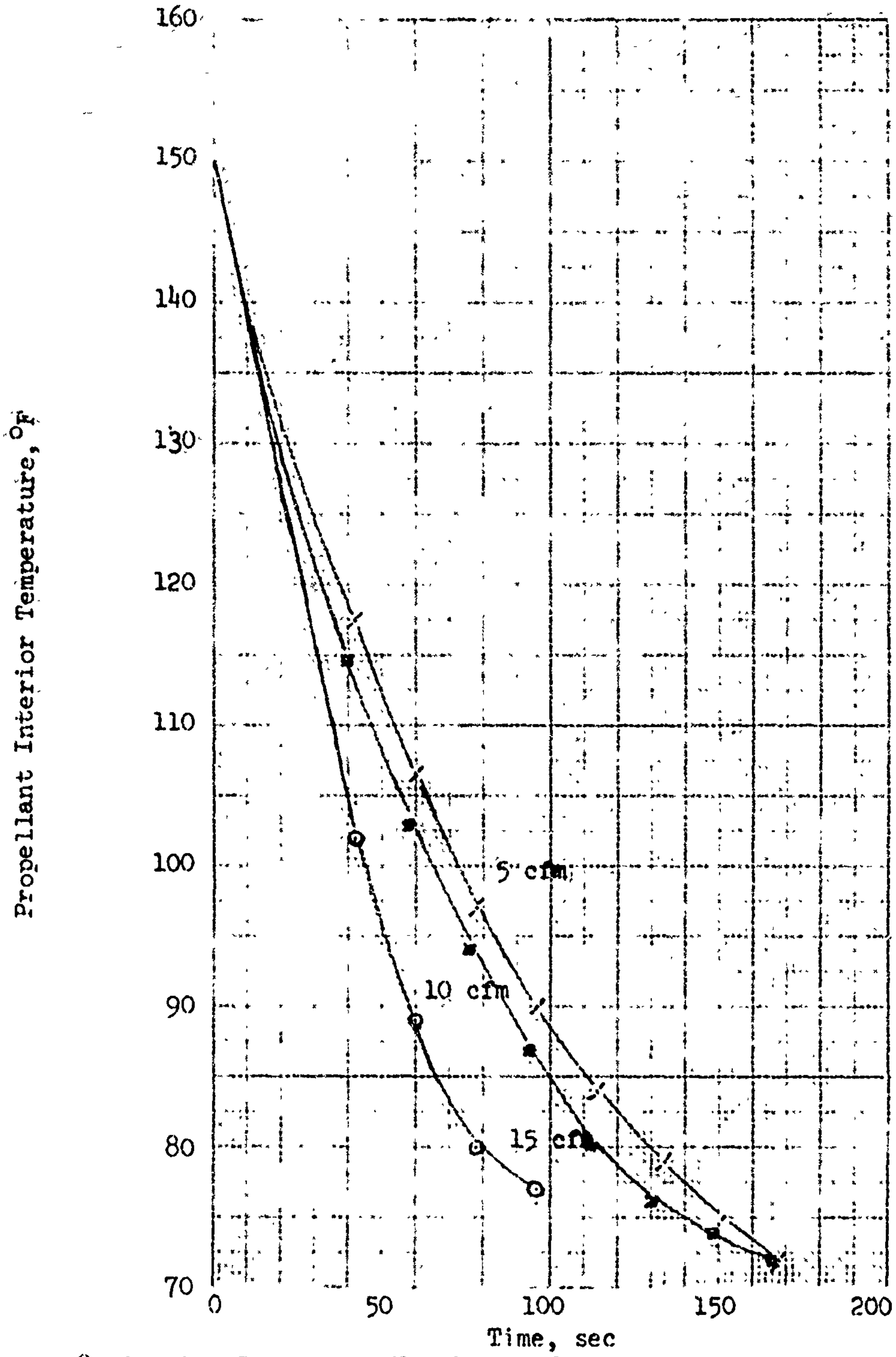


Figure 8, Cooling Curves for N-5 Carpet Strip for Coolant Air Temperature of 20°F

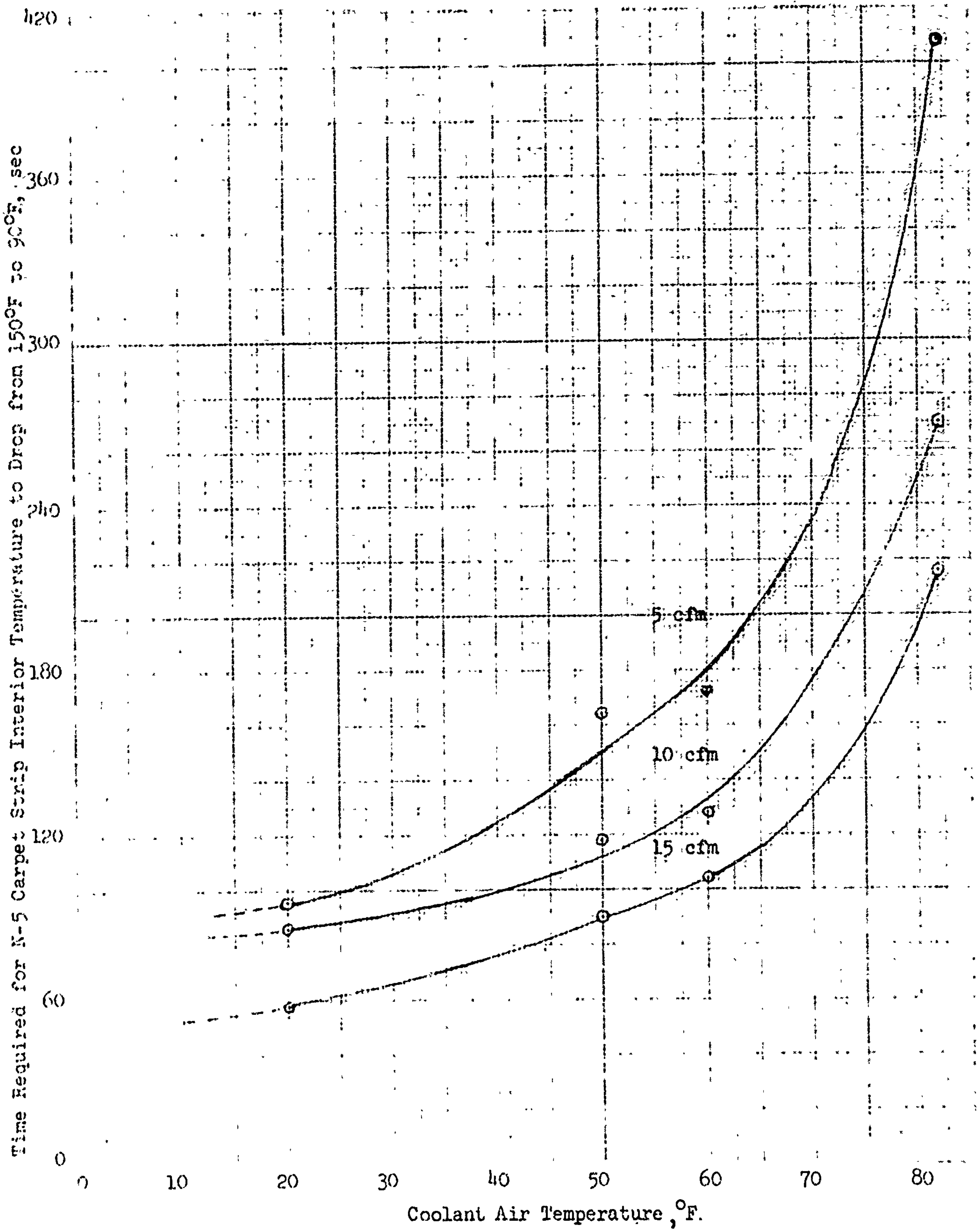


Figure 9, Cooling Time of N-5 Carpet Strip versus Coolant Air Temperature for a Constant Flow Rate

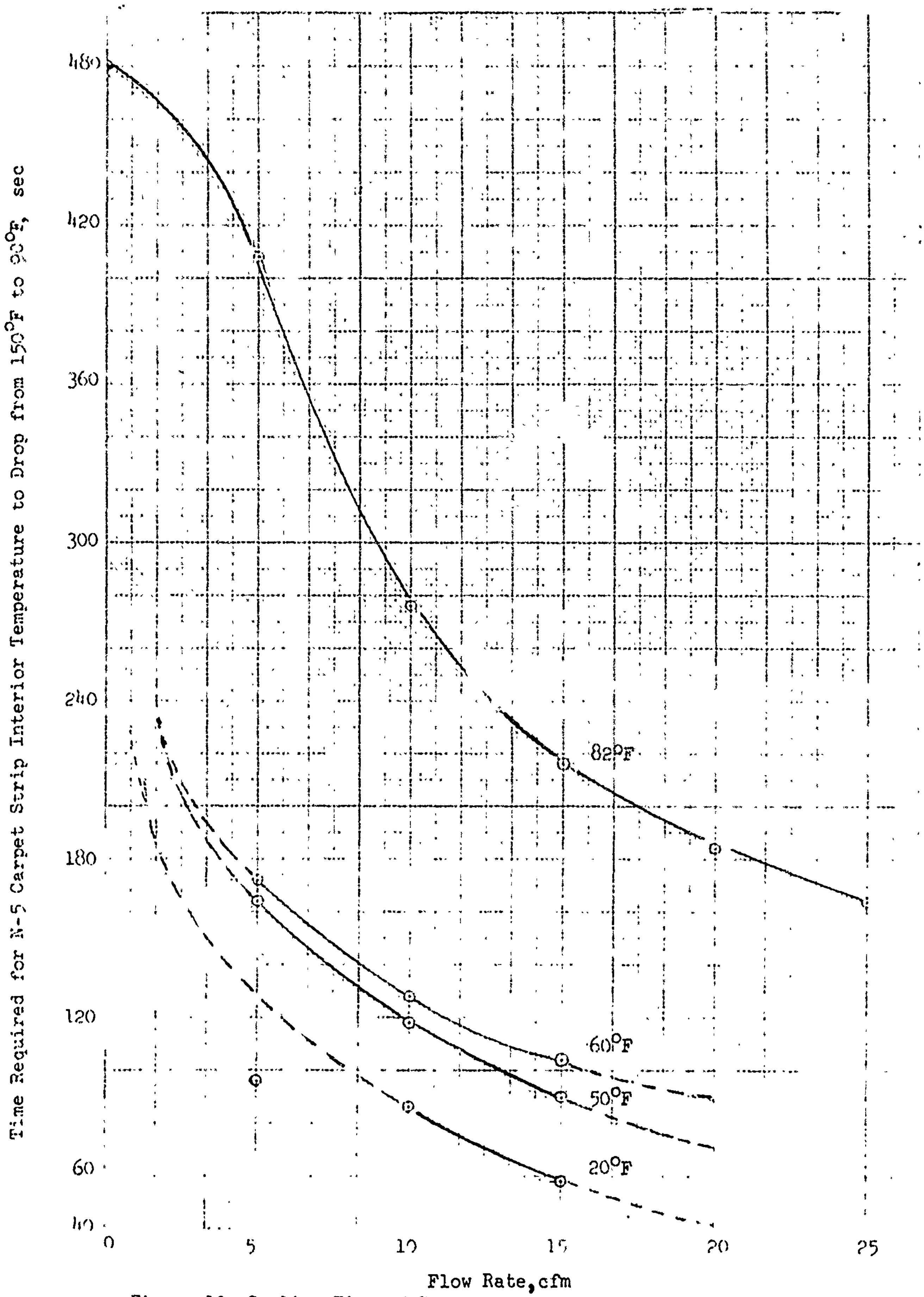


Figure 10, Cooling Time of N-5 Carpet Strip versus Coolant Air Flow Rate at Constant Coolant Air Temperature

Flower AAP Form SUN-309A (Rev. 1/69)

Memo-letter / HERCULES INCORPORATED

DATE: April 25, 1969

TO: J. A. Montgomery

FROM: B. K. Kedigh

SUBJECT: Determination of the Drying Characteristics of a Pre-Roll Sheet
PE 105, Task A-5

This study produced the drying characteristics of N-5 sheet propellant by convective heat at 190 to 250°F. The data obtained supports the proposal of including a convective heat drying process as the propellant sheet is removed from the pre-roll mill. The time required to lower the propellant moisture to the desired level depends on the oven temperature.

Propellant (N-5) differential roll sheets with a cook time of 1 minute 15 seconds were used for this experiment. Samples were cut into 4x5x1/16-inch sizes and placed in a convective oven for various times and temperatures. The initial and after cooking moisture contents were determined and plotted, on the attached graphs, as percent moisture loss to time and temperature.

The 1 percent moisture loss was achieved in 14 minutes at 190°F, 10 minutes at 210°F, 8 minutes at 230°F, and 6 minutes at 250°F.

Fewer observations were made at the elevated temperature (250°F) due to a slight color change and excess fuming of the propellant.

It is recommended that future lab work include a forced heated air type drying oven for lowering the moisture content at a faster rate.

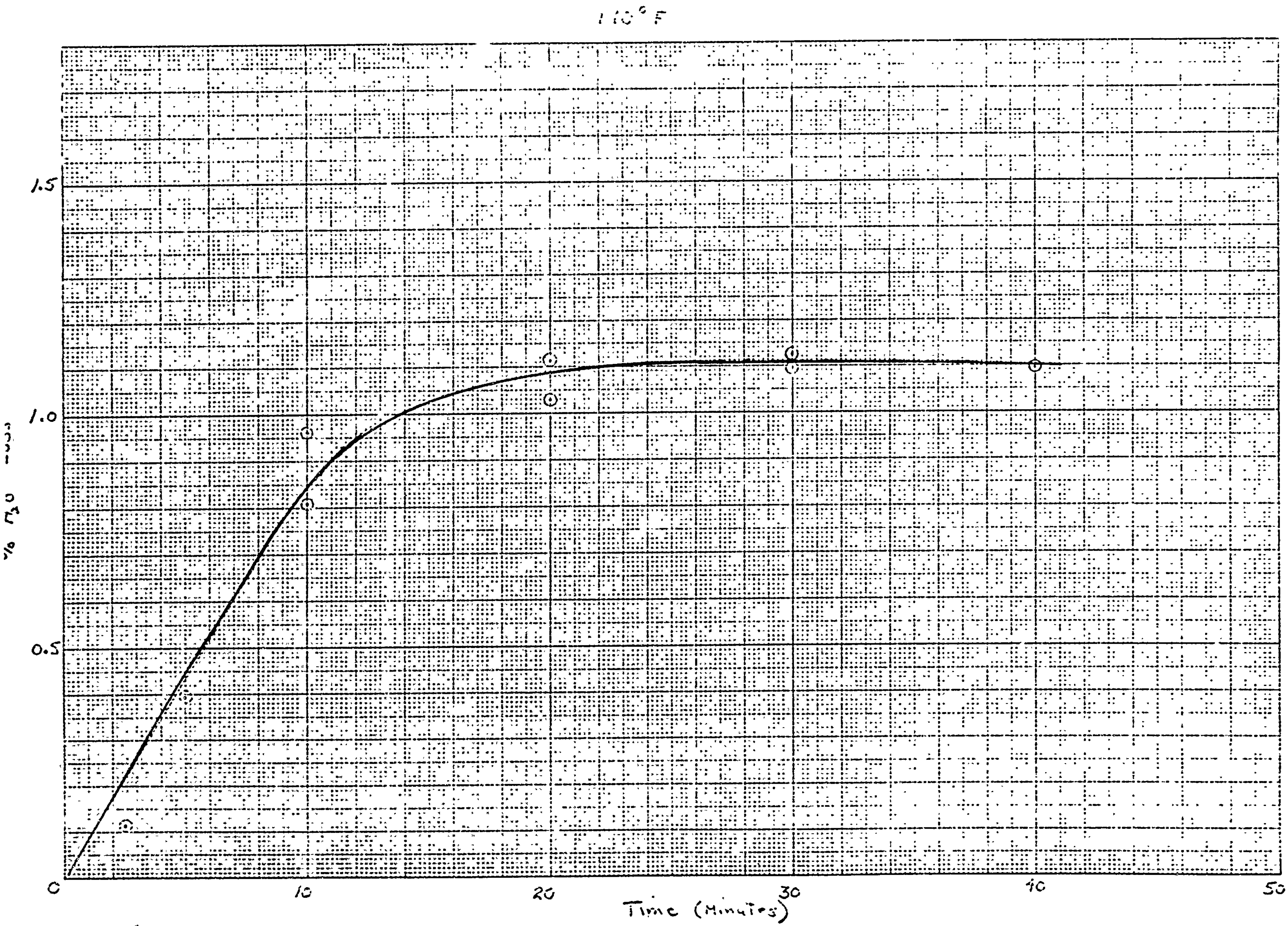
It might also be advisable, for future testing, at elevated temperatures (250°F) for sustained periods to make chemical analysis of the product for possible breakdown.

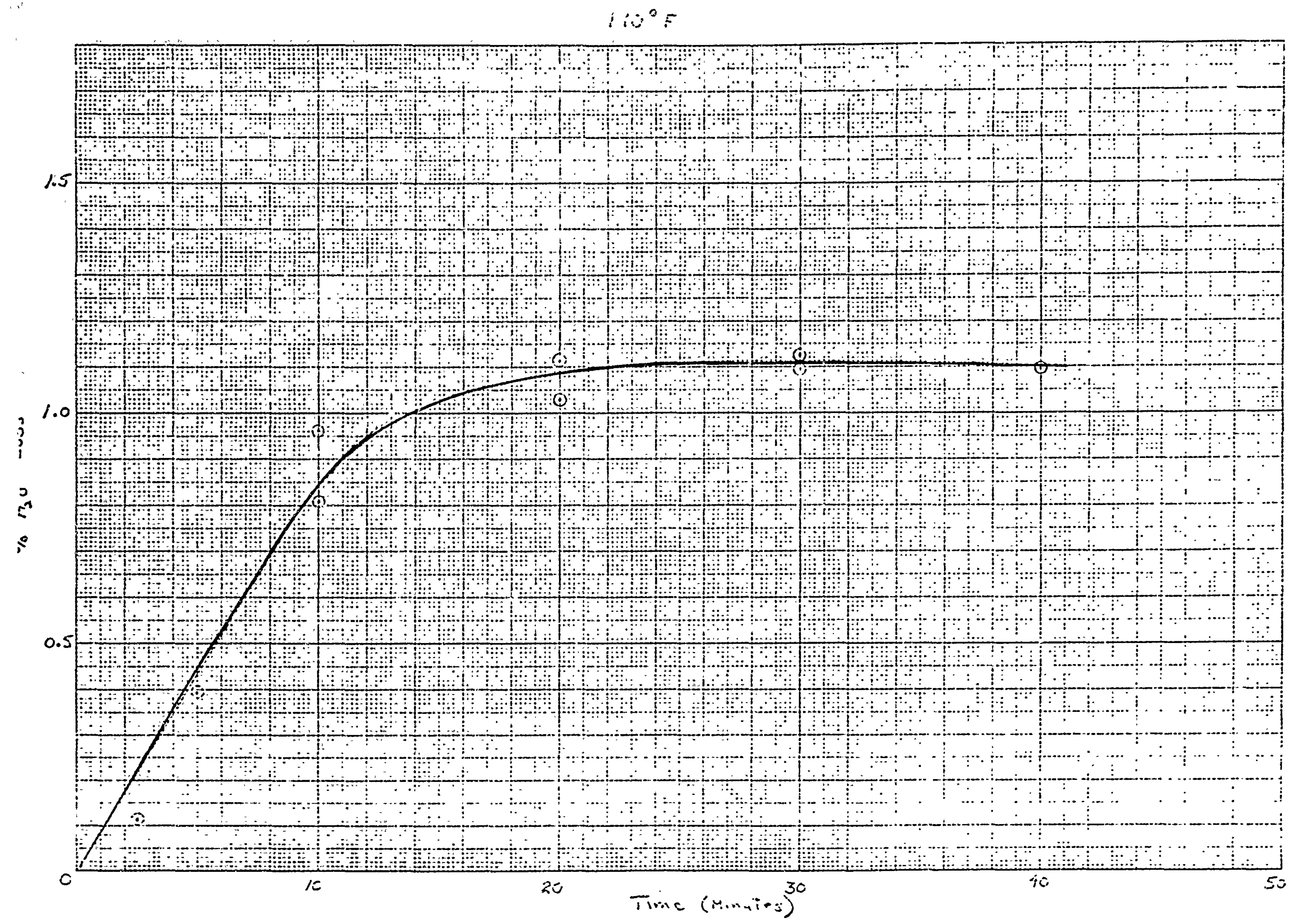
B. K. Kedigh
B. K. Kedigh
Tech. Foreman

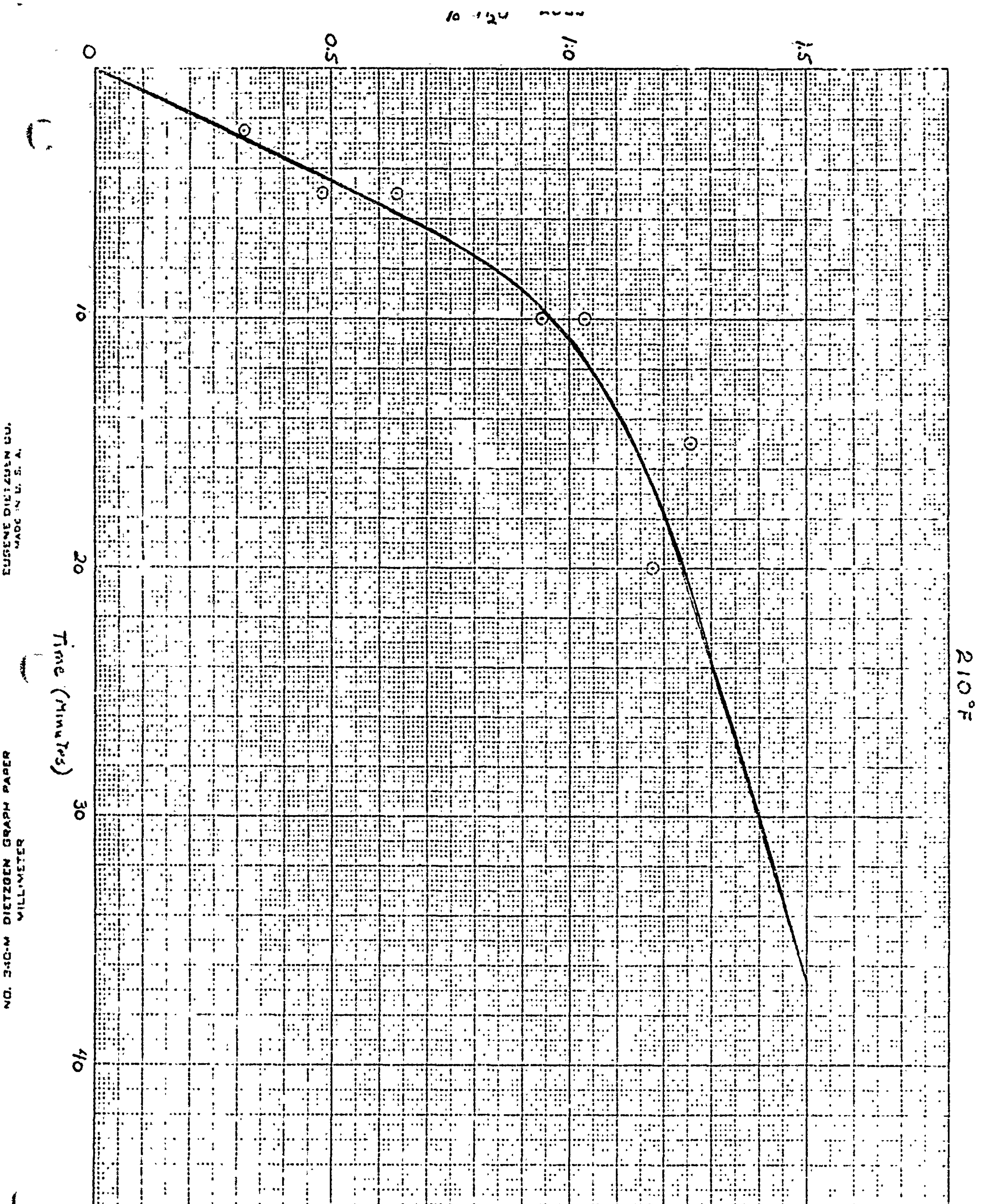
Avg sample moisture = 1.3% with variation from 1.1% to 1.4%

BKK/mvs

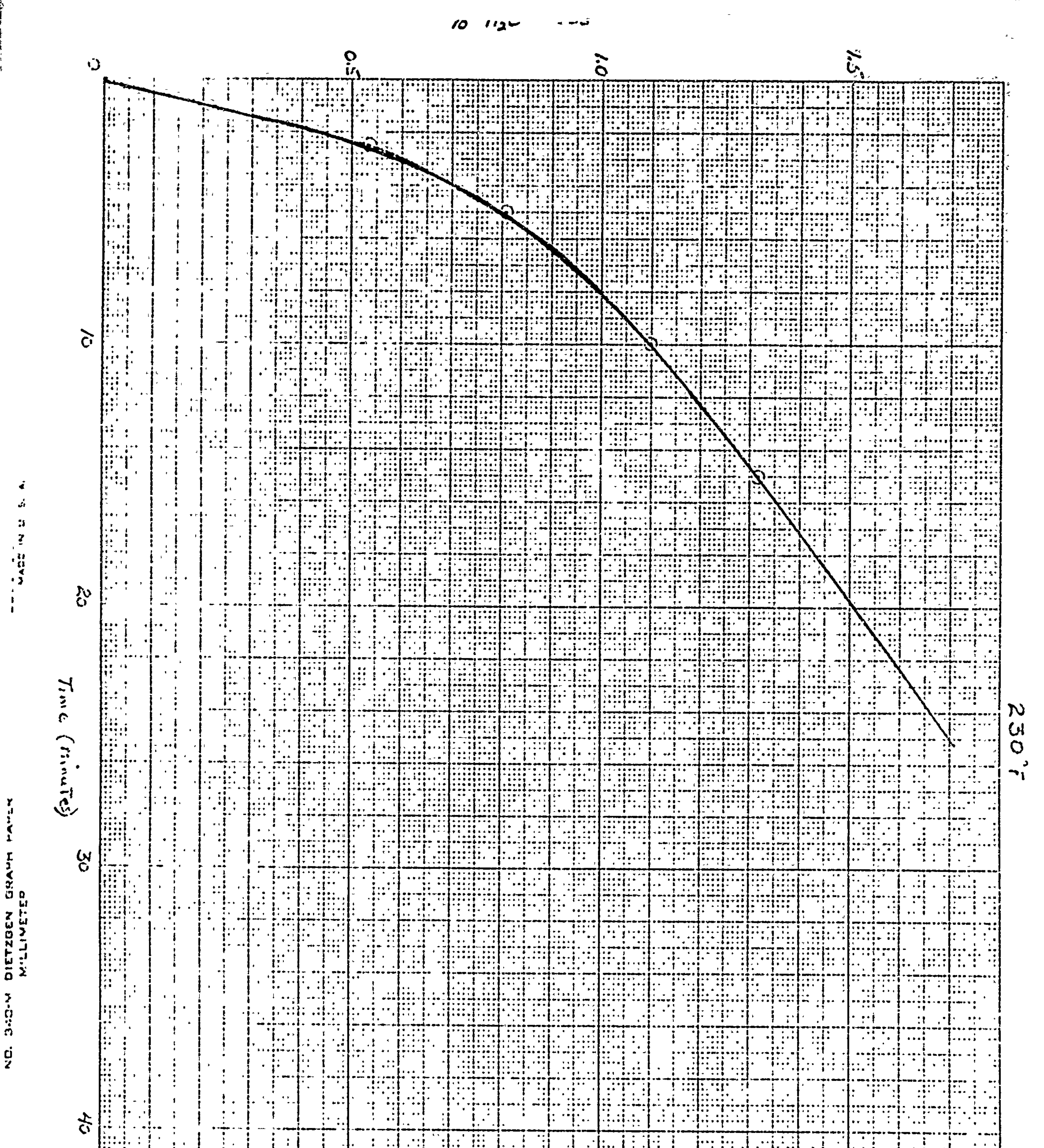
cc: file


110° F
1.5
1.0
0.5
0
10
20
30
40
50
Time (Minutes)

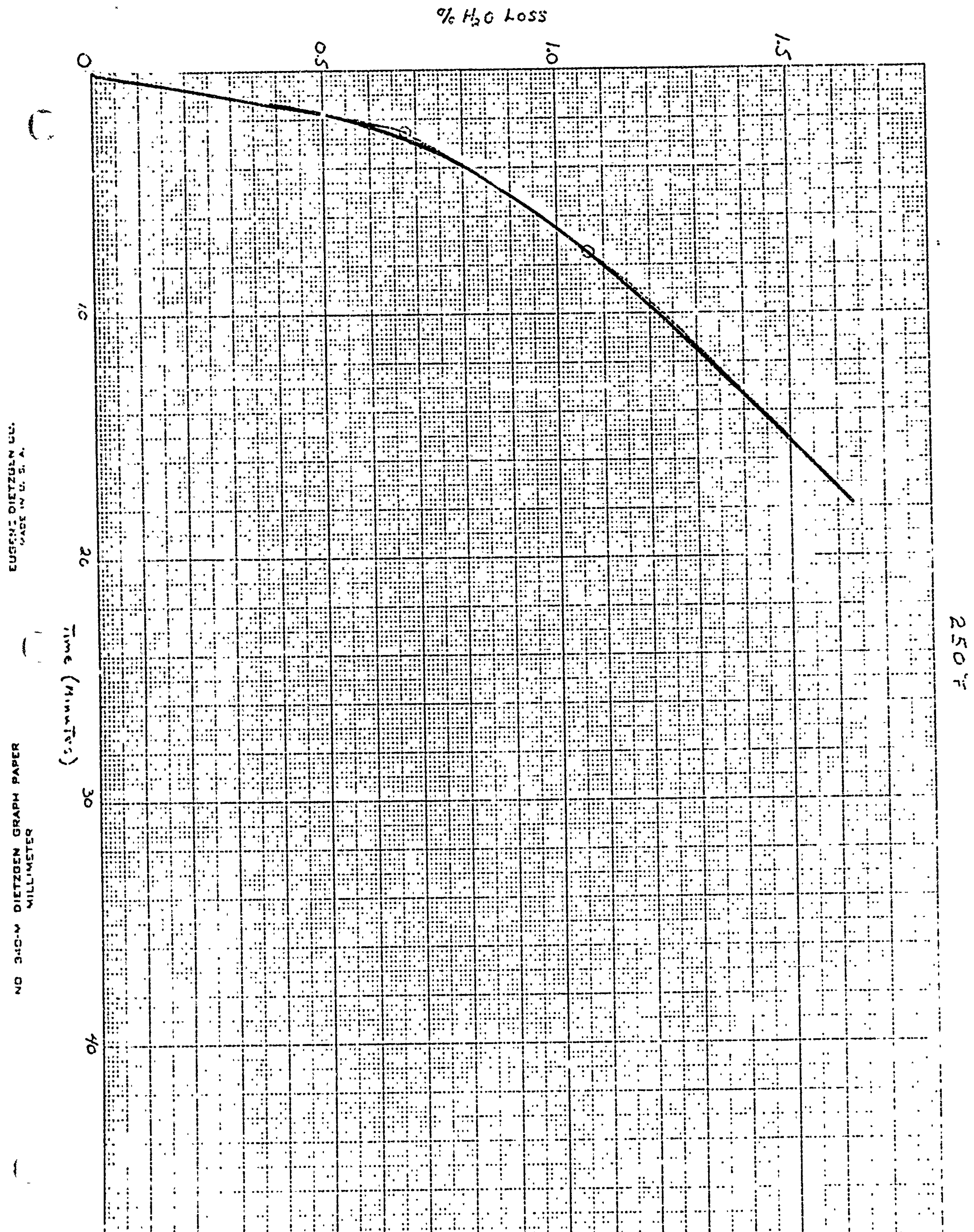

110°F
% H2O
1.5
1.0
0.5
0
10
20
30
40
50
Time (Minutes)



0
0.5
1.0
1.5
0
10
20
30
40
50
Time (Minutes)
210°F
EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 340-M DIETZGEN GRAPH PAPER
MILLIMETER



0
0.5
1.0
1.5
10
20
30
40
50
Time (minutes)
230°F
NO. 340-M DIETZGEN GRAPH PAPER
MILLIMETER
MADE IN U.S.A.



% H2O LOSS
0
0.5
1.0
1.5
10
20
30
40
50
Time (Minutes)
250°F
EUGENE DIETZGEN CO.
MADE IN U.S.A.
NO 340-M DIETZGEN GRAPH PAPER
MILLIMETER

Project P.E. 105

Design Engineering for Next Generation
of Mechanized Roll Facility

Special Test Report

List of Drawings and Sketches

SAAP 7659	Low Range Radiation Pyrometer Details
SAAP 7660	Low Range Radiation Pyrometer Assembly
SK-SAAP 3045	Radiation Pyrometer Alteration
SK-SAAP 3046	Mechanized Roll - Guide Plate Spacer for Test A-7
SK-SAAP 3047	Mechanized Roll - Guide Plate Detail for Test A-7
SK-SAAP 3048	Arrangement of Drying Compartment for Modification of Bay 1, Building 7807-3
SK-SAAP 3049	Frame and Plate Detail for Drying Compartment
SK-SAAP 3076	Diagram of Hot Air Application to Differential Sheet
SK-SAAP 3077	Air Dryer Pipe Assembly
SK-SAAP 3078	Mechanized Roll - Arrangement of Strip Coolers on No. 5 Conveyor
SK-SAAP 3079	Air Diffuser (36") for Strip Cooling of Propellant
SK-SAAP 3080	Air Diffuser (84') for Strip Cooling of Propellant

Funding Status

Amount Funded		$83,500
Amount Expended		
Exempt	$37,931	
Non-Exempt	16,216	
Wage	2,524	
Material/Expense	13,896	
Travel	318	
G & A	12,604	
Total	$83,489	

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Hercules Incorporated Sunflower Army Ammunition Plant Lawrence, Kansas 66044	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP N/A

3 REPORT TITLE

Design Engineering for the Next Generation Mechanized Roll Facility

4. DESCRIPTIVE ‹ TES (Type of report and inclusive dates)

Final ɛport - 15 Apr'l 1970

5. AUTHOR(S) (First name, middle initial, last name)

James A. Montgomery and John S. Lampkin

6 REPORT DATE 15 April 1970	7a. TOTAL NO. OF PAGES 176	7b. NO. OF REFS -
8a. CONTRACT OR GRANT NO. DA-11-173-AMC-42(A) b. PROJECT NO. 4810.16.3698.2 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) SUN 143-33; 4-15-70 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) None	

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited

11 SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY Department of Army Ammunition Procurement & Supply Agency Joliet, Illinois 60436

13 ABSTRACT

Design engineering work on the next generation solventless propellant mechanized rolling facilities was conducted. Design criteria was developed and submitted to the Corps of Engineers so that the updated facility could be constructed. (U)

Results of plant-scale evaluations of proposed process changes are discussed. Specifications and design criteria on the major production equipment are also included. (U)

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Mechanized Rolling						
Solventless Propellant Processing						

Unclassified
Security Classification