UMC C90 4/26/71

Cleveland, Ohio
April 1, 1952

LEOPOLD

MEMORANDUM For Facilities Engineering Files

BY

Subject: Conference on Proposed Rocket Facilities, March 27, 1952

1. Present at subject conference were:

A. Silverstein
B. G. Gulick (part)
W. T. Olson
J. L. Sloop
D. W. Berg
J. H. Nitchman
M. L. Hyman

2. The feasibility of locating a facility in the South-40 area for testing 100,000-pound thrust rockets was demonstrated by presentation of a preliminary layout based on Scheme A. (This scheme employs dry gas coolers, gas holders, and a recovery or scrubbing system for the hydrogen fluoride and fluorine.) The estimated cost was discussed. There was extensive discussion on the safety aspects of the layout, desirable disposition of hazardous structures, acoustical problems, etc. Other possible schemes and layouts were discussed briefly.

3. The important conclusions reached in conference are summarized:

(a) The target cost for first stage construction in the South-40 area should not exceed $6 million. Preferably, the cost should be about $4.5 million.

(b) Design for first stage construction should be based on the future development of the area into the full-scale 100,000-pound thrust facility. Initial design should include required features for operation of fluorine oxidant rockets of 20,000-pound thrust.

(c) Aesthetic values should be considered in layouts. Models should be made to demonstrate attractive appearance.

(d) Initial design and layout for budget consideration should proceed from engineering data which are known and available for immediate application. It was acknowledged that changes could be made at a later time if improvements in scheme or design become known.

(e) Delete test cells not part of the toxic exhaust system. This infers one group of test cells with space allowed for future expansion.

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[redacted]

(f) Where feasible, provision should be made for lateral suppression of explosion forces attendant to hazardous structures.

(g) Recovery of hydrogen fluoride from the exhaust products for conversion to fluorine is to be considered on the basis of economics of procurement cost vs. production cost and with consideration given to problems of transporting and handling chemicals.

(h) Design, layouts, estimates, and general engineering should proceed immediately towards presentation of Form 607 by May 1, 1952. Present determination group shall remain intact for this purpose.

(i) Messrs. W. T. Olson and J. L. Sloop are to present their requirements in light of the conclusions summarized here.

4. The proposed rocket facility at PSL was mentioned. No further consideration is to be given this proposal because of research objectives. An alternate was suggested using the new 24-inch air line in HEFL area for operation of ejectors. These ejectors would simulate continuous altitude conditions for small rocket work.

5. The noise attenuation problem is to be given further study, especially low frequency sound.

Marshall L. Hyman

Marshall L. Hyman
Chemical Engineer

cc: A. Silverstein
W. T. Olson
J. L. Sloop
D. W. Berg
M. L. Hyman
J. H. Mitchman

MLH:mlh
DWB
BGG

[redacted]

NACA-Lewis

1954 Budget

Cleveland, Ohio
April 14, 1952

MEMORANDUM For Those Concerned

Subject: Specifications and suggestions for proposed rocket test facility

1. Purpose: Provide research facilities for the study of rocket engine problems involving high energy rocket propellant combinations such as fluorine-hydrazine, fluorine-ammonia, and oxygen-hydrogen and other propellant combinations such as oxygen-gasoline and acid-gasoline.

2. Engine size and maximum operating time: For engines using fluorine and hydrogen - 20,000 pounds thrust for 3 minutes; for engines using nitric acid, 20,000 pounds thrust for 6 minutes; for engines using gasoline and oxygen, 100,000 pounds thrust for 3 minutes.

3. Location: S-40 area.

4. General description: Five test areas consisting of test cell, propellant tanks and pumping, service and control; main fuel and oxidizer storage tanks and distribution lines; exhaust gas scrubbers and sound attenuators; a hydrogen liquefaction plant, a fluorine generation plant, and an operations building containing a shop, central instrument room, chemistry laboratory, physical measurement laboratory, and offices.

5. Test cells

A. General Description

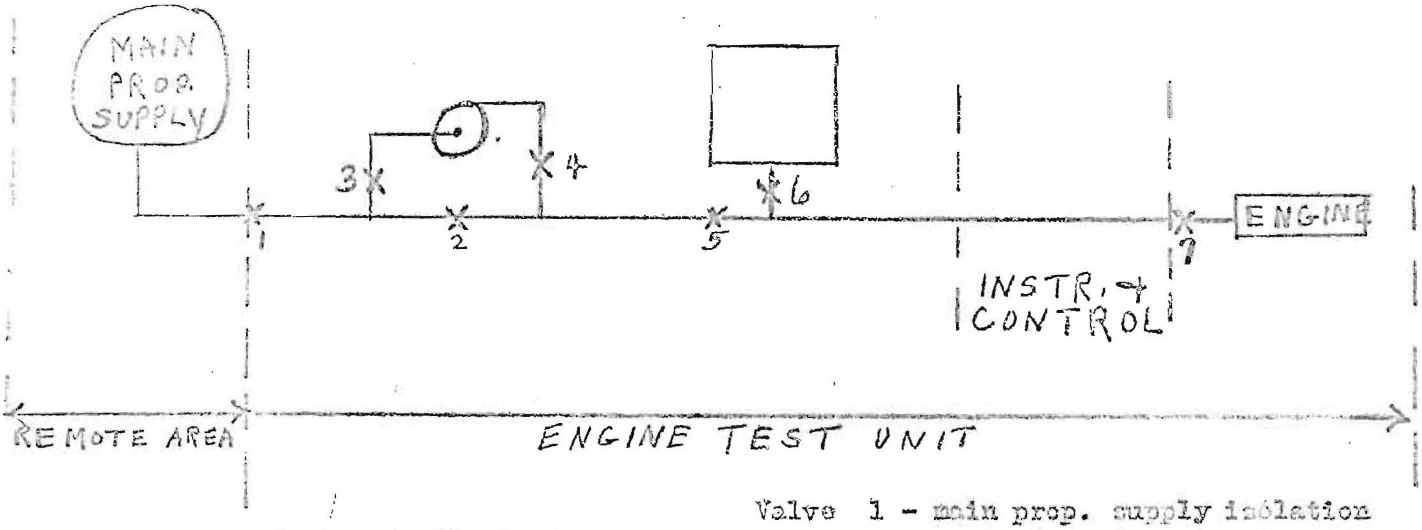
Five; two cells for engines to 20,000 thrust using liquid fluorine and liquid oxygen as oxidizers; ammonia, hydrogen, hydrazine, or hydrocarbons as fuels; two cells for engines to 20,000 thrust using liquid oxygen, and nitric acid as oxidizers; ammonia, hydrazine, or hydrocarbons as fuels; one cell for engines to 100,000 thrust using liquid oxygen as oxidizer and hydrocarbons as fuels.

Each engine test unit consists of four main parts: (1) engine, (2) auxiliary equipment (including pumps, tanks, valves, instrumentation, etc.) (3) service, and (4) engine control

Type A - 1+2
B - 3+4

B. Test Cell Operation

The type A test cells (fluorine to 20,000 pounds thrust) and type B test cells (oxygen-acid to 20,000 pounds thrust) shall be capable of operation in three ways as illustrated schematically.



Note: Duplicate for second propellant

Valve 1 - main prop. supply isolation at edge of test area
2 - pump by-pass
3 & 4 - pump isolation
5 - main prop. supply isolation
6 - pressure tank isolation
7 - propellant flow control

Cell Operation:

(1) Direct feed; from main tank to inst. and control to engine (having its own pumps); Valves 1, 2, 5, 7 open; Valves 3, 4, 6 closed. Main propellant tank pressurized to deliver required flow to engine at 25 psig to avoid cavitation.

(2) Laboratory pump; main tank to laboratory pump to instrument and control bay to engine. Valves 1, 3, 4, 5, 7 open; Valves 2, 6 closed.

(3) Pressurized feed from cell tank; main tank fills cell tank then cell tank pressurized. For filling Valves 1, 2, 5, 6 open, Valves 3, 4, and 7 closed. For engine feed from pressurized tank, Valves 6 and 7 open, others closed.

The above operation is illustrative only and does not represent all the valves and other equipment needed.

Test cell (No. 5 oxygen-gasoline to 100,000 pounds thrust) will be for self-contained engine test and will not have a laboratory pump or test cell tankage.

C. <u>Cell Layout</u>

The cell should be laid out in a simple, straight-flow manner. Experience has shown that appreciable mechanic time can be saved if work can continue safely in one cell while another is loading and operating. The engine should be separated from the auxiliary equipment for protection against fires or small explosions. Drives for propellant pumps should be similarly protected. A basic safety principle is to keep sizeable quantities of propellant away from the engine which is the principal fire and explosion hazard. Service in the test area is principally set up, installation, and operation maintenance, and could, if suitably protected from average fume or fire damage, be in the test cell or immediately adjacent. The control room serves as the safety room during operation and hence must be protected from explosions, fires, or fumes. A suggested test cell layout is attached. (Dimensions are approximate).

6. <u>Exhaust gas disposal</u>: Provide for the removal of HF from exhaust of two 20,000-pound thrust cells and of NO_2 from exhaust of the other two 20,000-pound thrust cells. At present a wet scrubber method where a dilute caustic is introduced into the exhaust stream appears promising for HF. Results of experimental studies of this scrubbing method will be supplied in a separate memorandum. Work is also in progress on measurement of NO_2 in the exhaust.

7. <u>Noise abatement</u>: All cells must have means to reduce engine noise to an acceptable level. Frequency and Sound intensity data are being obtained. One promising method for sound absorption is to introduce water into the exhaust stream.

8. <u>Propellant flow rates</u>

Propellant combination	Theoretical specific impulse % Fuel	Max Oxid* flow (lb/sec/1000# thrust)	Max fuel* flow (lb/sec)/1000# thrust
F_2-NH_3	300-278 / 19 - 42	3.0	1.7

Propellant combination	Theoretical specific impulse %Fuel ✓	Max Oxid* flow (lb/sec)/1000# thrust	Max fuel* flow (lb/sec)/1000# thrust
$F_2 - H_2$	3[illegible]0-330 / 4-35	3.2	1.2
✓ $O_2 - H_2$	342-339 / 20-33	2.6	1.1
$O_2 - NH_3$	225-209 / 35-60	3.2	3.2
O_2-gasoline	240-260 / 20-35	3.8	1.7
HNO_3-gasoline	225-222 / 14-19	4.1	1.7

*Increased 10% for incomplete comb.

9. Main propellant tanks

Working pressure psig	Propellant	Max impulse per run thrust x time 10^6	Quantity lbs.	Vol cu ft	Cells served	Max flow rate lb/sec*
50	Liq O_2	18	68,000	956**	all	76 (1-4) 380 (#5)
50	HNO_3	7.5	30,700	328**	3&4	82
50	F_2	3.6	11,500	118**	1&2	64
200	NH_3	3.6	11,500	271**	all	64
200	H_2	3.6	4,300	971**	1&2	24
50	Hydrocarbons	18	31,000	710**	all	34(1-4) 170(#5)
25	Nitrogen	---	---	900	all	10

Note: Total quantity is maximum flow rate times maximum impulse into cell and to pump

* Size distribution lines for maximum pressure drop of 25 psig.

** For two tanks. (OPTIONAL)

10. Propellant tank materials and construction

Propellant	Tank Material	Special Construction features
Liq O_2	304 SS	Vacuum jacket and insulated
HNO_3	(1) 99% al (2) 347 SS	----
F_2	Nickel	Vacuum jacketed and insulated refrigerated by liquid nitrogen
NH_3	Carbon steel	----
H_2	304 SS	Two vacuum jacketed and insulated refrigerated by gas H_2 and liquid nitrogen
Hydrocarbon	Carbon steel	----
Nitrogen	304 SS	Vacuum jacketed and insulated

11. Propellant pressure tanks for test cells
Working pressure 1500 psig (test to 3000 psig).

Cell	Propellant each cell	Vol. cu ft.
1 & 2	F_2	30
	O_2	50
(20,000 lb)	H_2	250
	NH_3 and hydrocarbons	50
3 & 4	O_2 & HNO_3	50
(20,000 lb)	NH_3 & hydrocarbon	50

The tank volumes are based on a total impulse of approximately 900,000 pound-seconds at mixture ratio for maximum amount of material concerned.

12. Hydrogen liquefaction: Provide liquefaction equipment sufficient for accumulating a maximum of 4300 pounds in the storage tanks ~~during~~ at end of a 2 week period. (This may be done with a liquefaction rate of approximately 18 lb/hr if approximately a 33% loss of a continuous 336 hour production is assumed for deicing, ortho-para conversion, and other heat losses). Provide adequate protection against fires and explosions.

new cells at 7000 amp? for

13. Fluorine generation: Maximum fluorine generation rate of 35 lb/hr: This can be met with five electrolytic cells 10 volts 5000 ampere each; each with a fluorine production of approximately 7 lb/hr; cells approximately 5 feet in diameter require space 10 ft. square per cell, cells heated by automatically regulated water-steam system electrolyte temperatures from 100° C to 150° C; provide motor-generator set for each cell; provide service and operations, chemistry laboratory and rooms as suggested by accompanying sketch.

14. Compressed gas supply and distribution system

(a) High pressure compressed gas supply and distribution line

Material to pressurise	Gas	Cells served	Supply pressure psig	Working pressure at test cell, psig	Volume at supply pressure	Total volume to be displaced per week	Cu ft SPT**
H_2	H_2	1 & 2	2000	1000	475	475	65,000
F_2		1 & 2	2000	1500	475	160	65,000
O_2F_2	He	all	2600	1000	620	1000	110,000
O_2, F_2		all	2600	1500	620	455	110,000
All fuels except F_2	N_2	all	2000	1000	1300	1300	177,000
		all	2000	1500	1300	326	177,000

Subject to revision

*Cells 1 and 2 are for use with fluorine
** This is the maximum amount to be supplied at the supply pressure each week from commercial cylinder tanks.

(b) Low pressure compressed gas distribution system

Gas	Cells	Pressure psig
He	1 & 2, Main F_2 storage tanks	50-500
N_2	All, Main fuel storage tanks	50-500

Used for purging, pressurizing tanks for pumping (both main tanks to cells and from cell tanks to main storage), operation of control valves, etc.

(c) An economical way of meeting requirements (a) and (b) would be to provide the required volume of (a) in multiple tanks, say in 5 groups. Start with only one of the five supply units on the distribution line; after the pressure on this tank falls to 1000 psi it could be switched to the low pressure distribution line and another high pressure set of tanks cut in on the high pressure distribution line. An economic study of the feasibility of using high pressure compressors to conserve low pressure gas should be made. Also investigate feasibility of supplying the compressed nitrogen from liquid nitrogen.

15. Operations building: Provide separate building for the following functions:

(a) Central Instrument Room - approx. 2000 sq. ft.
(b) Central shop - approx. 3500 sq. ft.
(c) Chemistry Laboratory - approx. 1500 sq. ft.
(d) Physical Laboratory - approx. 1000 sq. ft.
(e) Offices for 40 men including two private offices, and 3 conference rooms (20 men) plus drafting room for 5 men and computing room for 5 girls. (total 50 persons)
(Note: Use existing plan as a guide)

16. General layout: Suggest in-line arrangement of cells and propellant storage approximately similar to Dwg. 10,0002. Provide open distribution lines for propellants and high pressure nitrogen, hydrogen and helium at firing end of test cells. Provide a tunnel approximately 6' x 7' for open ducting for instrumentation, electric power, miscellaneous services (no flammable material) and for pedestrians. Use mounds to isolate cells and provide safely for personnel travelling between different areas. Provide for explosion and fire potential with the hydrogen liquefaction plant. The accompanying sketch illustrates the principles desired in the layout.

JS;mh

John L. Sloop
Chief, Rocket Branch

NACA-Lewis

Cleveland, Ohio
May 1, 1952

MEMORANDUM For Chief, Rocket Branch

Subject: Progress report on the experimental investigation of the removal of hydrogen fluoride from the exhaust of a 100-pound thrust liquid-fluorine liquid-ammonia rocket

1. The rocket exhaust from fluorine-ammonia and fluorine-hydrogen engines contains from 80 to 100 weight percent hydrogen fluoride. The hydrogen fluoride is extremely toxic and must be removed before the rocket exhaust gases are introduced to the atmosphere. The maximum allowable concentration of hydrogen fluoride gas for a constant exposure is approximately 3 parts per million (P.P.M.) or 0.0025 mg/liter while the intolerable limit is about 120 P.P.M. (0.1 mg/liter) (reference 1).

2. The method of hydrogen fluoride gas removal under investigation at the present time consists of introducing a sodium hydroxide solution into a duct through which the hot rocket exhaust gases pass before release to the atmosphere. The purpose of the caustic solution is to cool the gases and absorb the hydrogen fluoride. Two separate duct systems have been under investigation; one consisting of a 24-inch diameter duct with provisions for the use of a spray bar, spray ring or jet wheel caustic distribution system, and the second consisting of an 8-inch diameter duct provided with a jet wheel caustic distribution system. In addition, a disk and donut type tower was used with the 24-inch duct (fig. 1). The three station caustic supply system in the 24-inch duct was designed to have the spray bar serve to lower the velocity of the exhaust gas and promote mixing of the caustic solution with the hot gases, the spray ring section to cool and absorb some of the hydrogen fluoride and the tower section to absorb the remaining toxic gas. Since the 24-inch duct system was designed for a [illegible]-pound thrust fluorine-ammonia rocket, an 8-inch duct was designed for use with the 100-pound thrust unit under investigation. The single station jet wheel caustic injection system was designed to be installed as close to the exhaust jet as possible, utilizing the kinetic energy of the rocket exhaust to promote rapid vaporization and mixing, resulting in more efficient removal of the hydrogen fluoride. A description of the apparatus and gas sampling technique is given in Appendix A.

3. The results obtained to date are summarized in tables I and II. The initial runs utilized a 24-inch diameter duct with a 4 percent caustic solution issuing from the three sections; spray bar, spray ring and tower, and resulted in the removal of approximately all the HF in the rocket exhaust. The total caustic flow used was

approximately 146 pounds per second of caustic per one pound per second fluorine flow (lbs./lb.). One run was made without the use of an air restrictor cone and resulted in exceedingly large clouds of smoke exhausting from the tower. The next runs were made under the same conditions but utilizing an air restrictor on the duct to reduce the quantity of air induced. Very small quantities of smoke were observed to exit from the tower which may indicate the advantage of designing a duct system incorporating provisions to prevent or reduce the induction of air.

4. Three runs were made in the 24-inch duct using the first two sections (spray bar and spray rings) for the introduction of a 2 percent caustic solution. A total of approximately 140 pounds per pound caustic solution was used. A gas sample analysis was obtained for Section A in one run and Section B in the second run. The results indicate a hydrogen fluoride gas concentration of approximately 855 PPM in Section A and about 360 PPM in Section B. The air restrictor cone was used for these runs and all succeeding runs in which the duct was employed.

5. Two runs were made in the 24-inch duct using only the spray bar section for the introduction of a 2 percent caustic solution. The flow rate of the first run was 59.5 lb/lb and resulted in a hydrogen fluoride concentration of 953 PPm in Section A and 1023 PPm in Section B. Increasing the flow rate to 67 lb/lb resulted in a fluoride concentration of 572 PPM for Section A and 586 PPM in Section B.

6. In an effort to obtain better mixing and greater reaction time between the caustic solution and the hot exhaust gas, the method of introducing the caustic was changed from the spray bar to a jet wheel (see Appendix 1). Two runs were made using only the jet wheel in the 24-inch duct. The results obtained using a 2 percent caustic flow of 66.2 lb/lb indicated a hydrogen fluoride concentration of 282 PPM in Section A and 212 PPM in Section B. The second run using a 2 percent caustic flow of 83 lb/lb indicated a fluoride concentration of 261 PPM in Section A and 332 PPM in Section B.

7. One dry run was made in the 24-inch duct to obtain the hydrogen fluoride concentration in the duct without the use of a caustic solution. The analysis indicated a concentration of approximately 90,000 PPM of fluoride. Theoretical calculations for the 100-pound thrust rocket engine indicate that in a closed duct system (exclusion of induced air) the fluoride concentration should be about 800,000 PPM. Examination of the analytical procedure indicated that only enough sodium hydroxide was added to the collected gas sample to indicate a concentration of approximately 90,000 PPM. (See Appendix I).

8. To scale down the entire scrubbing unit, an 8-inch duct was substituted for the 24-inch duct with the gas sampling, temperature and pressure probes located in the same relative position as was in the 24-inch duct. The jet wheel, located 6 inches from the rocket engine nozzle has been used for the remainder of the runs made to date with the

8-inch duct. Several runs were made using 2 percent caustic through the jet wheel and resulted in a hydrogen fluoride concentration of 896 PPM in Section A and 205 PPM in Section B for a caustic flow rate of 86.3 lb/lb; 459 PPM in Section A and 205 PPM in Section B for a flow rate of 85.9 lb/lb; and 988 PPM in Section A and 431 PPM in Section B for a flow rate of 42.4 lb/lb.

9. In an effort to reduce the water requirements for the removal of fluoride, the concentration of sodium hydroxide was increased and the total flow of caustic solution decreased. By increasing the concentration of sodium hydroxide, it was assumed that more efficient removal of the hydrogen fluoride gas could be obtained by the formation of sodium fluoride. With the use of higher concentrations of sodium hydroxide, the presence of appreciable quantities of sodium fluoride in the sampling bottles would result in extremely high values of fluoride content which could not be reported as hydrogen fluoride gas. To prevent the possibility of capturing the solid sodium fluoride particles, glass wool coupled with fritted glass filters were installed between the duct and the sample bottle.

10. Two runs were made using 12.8 percent caustic with the glass wool filters installed before the gas collection vessel. The first run indicated hydrogen fluoride gas concentration of 87.2 PPM in Section A and 168 PPM in Section B with a total flow of 40 lb/lb. Using a total flow of 27 lb/lb of the 12.8 percent caustic resulted in a hydrogen fluoride gas concentration of 153 PPM in Section A and 159 PPM in Section B.

11. Two dry runs were made in the 8-inch duct and resulted in a hydrogen fluoride gas concentration of 186,000 PPM in Section B for the first run and 350,000 PPM in Section B for the second run. Examination of the sampling probes after each run showed the four tubes of Section A to be welded shut and the two tubes of Section B to be partially closed.

12. Additional runs are necessary in order to determine the following:

(a) The effect of the glass filters and glass sampling bottles on the possibility of absorbing hydrogen fluoride gas

(b) The hydrogen fluoride gas concentration in the duct under conditions of controlled air induction

(c) The hydrogen fluoride gas concentration under conditions of variable water and caustic flow

(d) The concentration of sodium fluoride exhausting to the atmosphere and contained in the waste water under the various operating conditions

13. Conclusions:

(a) The use of an air restrictor cone to reduce the quantity of air induced into the duct appears to be desirable.

(b) The principle of concentrating the introduction of the caustic solution as close to and as far into the hot cone of the rocket exhaust as possible rather than throughout the entire length of the duct should be followed.

(c) The use of a highly concentrated caustic solution is desirable and should be employed.

1. At equal caustic solution flows per pound of fluorine, concentrated sodium hydroxide (above the theoretical requirements) solutions are more efficient in removing hydrogen fluoride from the gas stream. At a flow rate of about 40 lbs/lb, a 2 percent caustic solution resulted in a hydrogen fluoride gas concentration of approximately 600 PPM while a 12.8 percent caustic solution resulted in a hydrogen fluoride gas concentration of 120 PPM.

2. Increasing the concentration of the caustic solution results in a great deal lower water flow requirement to obtain comparable hydrogen fluoride gas concentrations. For a gas concentration of about 120 PPM, the flow requirement using a 2 percent caustic solution is approximately 100 lb/lb while for a 12.8 percent caustic solution the flow requirement is 40 lb/lb.

3. Increasing the concentration of the caustic solution results in a great deal lower duct length requirement. Using a 2 percent caustic solution resulted in a difference of about 600 PPM in hydrogen fluoride gas concentration between the two sample stations located 8 feet apart. With the 12.8 percent caustic solution, the same hydrogen fluoride gas concentration was obtained for the two stations.

(d) The use of concentrated caustic solutions requires the use of equipment to remove the solid sodium fluoride particles before exhausting to the atmosphere. Studies should be made to determine methods of removing solid particles from gas streams. (Cyclone or venturi separators). Should a dilute solution of caustic be employed with large quantities of water, means of removing the sodium fluoride from the waste water should be developed to permit recycling.

Paul M. Ordin

APPENDIX I

1. Figure 1 is a diagram of the basic scrubbing system used in the test program. The system consisted of a 20 foot duct which carried the rocket exhaust from the engine to a disk and donut type baffle tower. The tower was 7 ft. square and 11 ft. high and contained a series of five baffles; 2 disks and 3 donuts. The caustic solution was prepared in a 2500 gallon tank and pressure fed through orifice flowmeters to the various stations in the scrubber system.

2. Initially a 24-inch diameter duct was used for the experimental work. The first run was made with the 2 foot duct located approximately 12" from the rocket engine. For the subsequent runs, an air restrictor cone was added to the duct which brought the entrance to within 1/4 inch of the engine and reduced the duct entrance to approximately 2-3/4" diameter.

3. Caustic solution (sodium hydroxide solution) was added at two stations in the duct. The first station located about 2 ft. from the engine, consisted of a spray bar of 2" pipe, 3 ft. long. The pipe was placed along the duct axis permitting the caustic solution to enter the gas stream through a series of ~~holes drilled~~ slots cut along the pipe length and around the circumference. The second injection station, located approximately 8 ft. downstream of the engine, consisted of three spray rings about one ft. apart with each ring containing a series of Monarch spray nozzle.

4. After a number of runs using the caustic solution injection systems as described above, an additional system was added to the duct. The method of injection consisted of introducing the caustic as close to and as far into the hot cone of the rocket exhaust as possible. A wheel made of a 1 foot diameter manifold having eight "spokes", lying along equally spaced diameters was used for introducing the caustic solution. The manifold was made of 1-inch tubing and the "spokes" which were welded to the manifold were of flattened 3/4" stainless steel tubing. Four of the spokes were 5" long and four 4" long and were alternately positioned on the manifold. (See fig. 2).

5. The final series of tests ~~were~~ was made in an eight-inch diameter duct using only the jet wheel as the injection system. An air restrictor cone brought the entrance of the duct to approximately 1/4" of the engine and was approximately 2-3/4" in diameter at the restrictor entrance. Photographs of the scrubber system are shown in figures 3 and 4.

6. Samples of the gas flowing through the duct were taken at three different stations. The first station was located about 9 ft. from the engine and the second station approximately 18 ft. from the engine. The third station, located at the very top of the tower was used for only two runs. Due to the large volume contained in the tower section, only two runs were made in which the caustic solution was added to the tower section. After these runs, the tower door was left open, making the further taking of top tower gas samples of no value.

7. The samples were collected in evacuated, two liter glass flasks, provided with glass stopcocks. A remote operating valve was located between the sampling probes and the flask. Each station had four probes, equally spaced along a diameter of the duct cross-section. The probes were manifolded before the operating valve. In this manner, an average sample for the cross-section was obtained. A vacuum of at least 25" Hg was maintained in the sample bottles and system up to the remote operating valve. Approximately 8 seconds after the rocket run had started, the valves were opened and a sample collected in the flask. After about 4 seconds, the valves were closed again. When the rocket run was over, the stopcocks on the flasks were closed and the flasks removed for gas analysis.

8. Treatment of the gas sample was begun within 15 minutes after they were taken. The pressure in the flask was measured after which 10 cc of a 2 percent N_aOH solution was added to the sample. The flask was re-sealed and at least two hours were allowed for the caustic to absorb and neutralize the hydrogen fluoride in the sample. The same quantity of 2 percent N_aOH was used for the initial blank runs and was found to be insufficient to neutralize all the HF present. Approximately 50 cc of a 10 percent N_aOH solution was used for the blank runs that followed. After about two hours or more, the samples were transferred for analysis and the sampling flasks washed with distilled water with the washings added to the water.

9. The analytical method used to determine the fluoride ion concentration in the sample is similar to that described in reference 1. The caustic washings were concentrated to approximately 25 ml placed into a distillation flask together with Ag_2SO_4, silicagel and 25 ml of 70 percent $HClO_4$. 100 ml of distillate were taken off at 135° - 140° C, kept basic to phenophthalein, neutralized, buffered and titrated with 0.04 N $Th(NO_3)_4$. Sufficient blanks and "knowns" were run to indicate the accuracy of the determination to be of the order of 2 percent of the amount determined plus 0.010 mg (the sensitivity of the method is about 0.01 mg F and the accuracy about 2 percent of the amount determined).

10. It is believed that the sample obtained is quite representative of the gas flowing in the duct. Entrained water (droplets) were eliminated from the sample by positioning the sampling probes downstream. In runs made using concentrations of caustic above 2 percent, glass wool filters were placed before the sampling flasks to prevent the collection of solid sodium fluoride. The time for the sampling system to go from a pressure of -25" Hg to 0" Hg was 2 seconds for the plain sampling system, 4 seconds for the glass wool filter system, and 5 seconds for the glass wool, fritted glass sampling system. The average contact time of the gas with the glass wool is about 1.6×10^{-2} seconds indicating the improbability of a reaction between the HF gas and the glass wool.

Reference 1. Ind. & Eng. Chem. Anal. Ed. pg. 71, 1939.

TABLE I

24" Duct A 3.14 ft²

F_2 flow lb/sec	Caustic solution flow lb/sec W_{cs}	Percent caustic	$\frac{W_{cs}}{W_{F,2}}$	Analysis A PPM. HF	Analysis B	Flow injection 1 Spray bar	Flow injection 2 Spray rings	Flow injection 3 Tower	Flow injection 4 Jet wheel	Press. cone in. H_2O	Press. 1 in. H_2O	Temp 1 °F Dry bulb	Temp 1 °F Wet bulb	Temp 2 °F Dry bulb	Temp 2 °F Wet bulb	$\frac{W_{cs}}{W_{F/A}}$
0.312	~~.66~~	4	211	No Anal.[a]		21.9	22.1	22	No	X	2.8	No	Reading			
.313	~~.66~~	4	211	No Anal.[a]		21.9	22.1	22	No	X	-.3					
.4106	60.3 40.6	4	97.5 ~~148~~	138	21	20.	20.6	20.3	No	X	X					
.3566	49.9	2	140	855	—[b]	27.3	22.6	No	No	5.3	4.95	360	149	96	82	
.3354	50.1	2	152.1	—[b]	360	23.6	26.5	No	No	-5.6	-5.0	310	146	86	—	
.3908	23.7	2	59.5	953	1023	23.7	No	No	No	-5.6	-5.0					
.3543	23.7	2	67.	572	586	23.7	No	No	No	-5.7	-5.1					
.3810	25.2	2	66.2	282	212	No	No	No	25.2	-5.0	-2.9	110	115	117	98	177.0
.2845	23.6	2	83.	261	332	No	No	No	23.6	-5.2	-3.4	100	103	120	103	261.0
.3647	No		0	84,800[c]	98,900[c]	No	No	No	No	-15.1	-5.4					

[a] No vacuum maintained on sample bottle

[b] Lost sample in distillation

[c] Only 10 cc of 2 percent N_aOH added which could indicate a maximum of only approximately 95,000 PPM

TABLE II

8" Duct, Jet Wheel A 0.35 ft^2

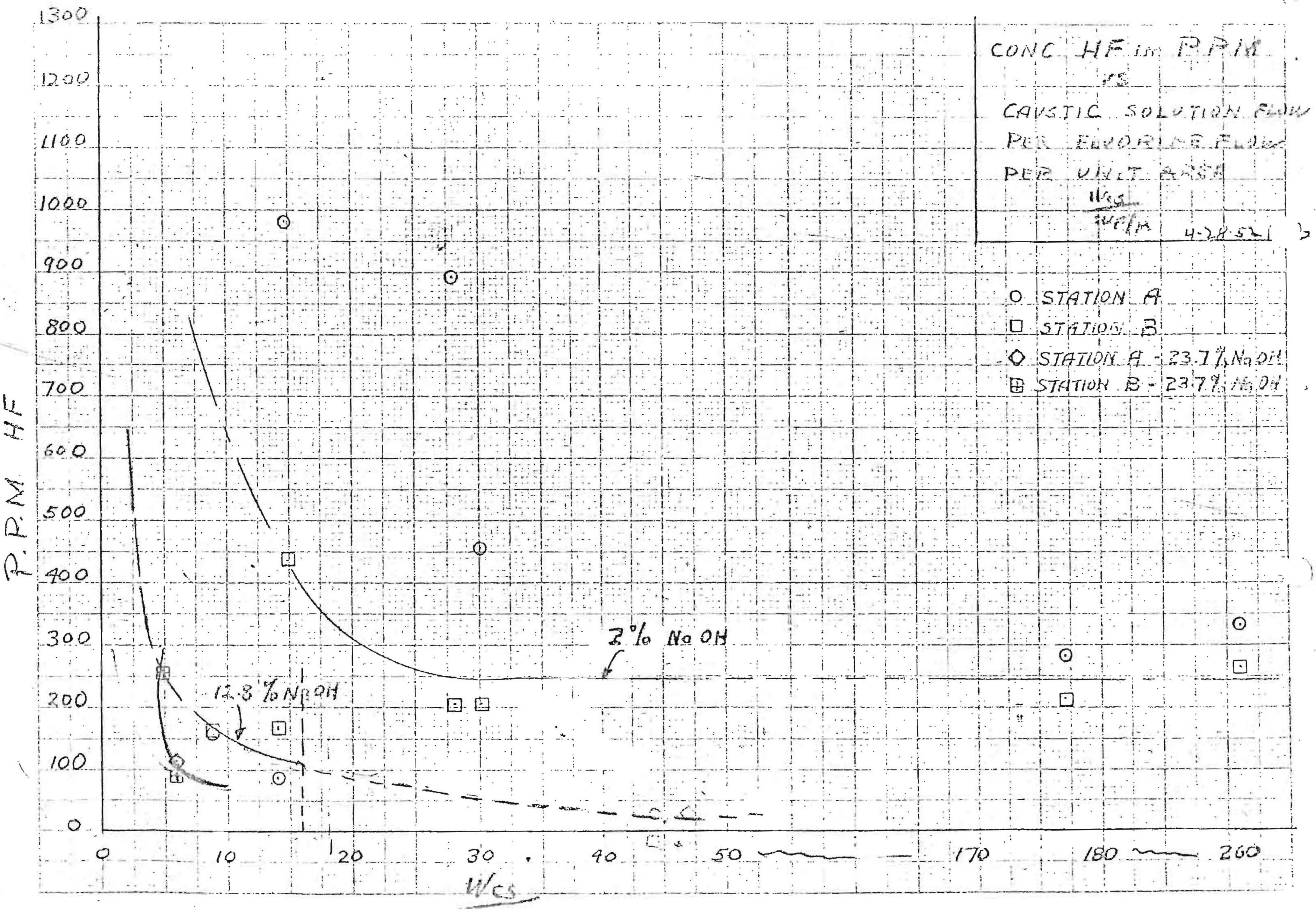
F_2 flow lb/sec	Caustic solution flow lb/sec W_{cs}	Percent caustic	$\frac{W_{cs}}{W_{F,2}}$ 3 1	Analysis A (PPM. HF)	Analysis B (PPM. HF)	Sample B Without Filter	Press. cone in. H_2O	Press. 1 in. H_2O	$\frac{W_{cs}/W_{F,2}}{A}$	Temp 1 °F Dry bulb	Temp 1 °F Wet bulb	Temp 2 °F Dry bulb	Temp 2 °F Wet bulb
0.3016	24.2	2	80.3	1896	205		-10.0	0.4	28.1	107	127	127	---
.2174	18.7	2	85.9	459	205		-11.0	0.5	30.1	121	135	152	---
.5566	23.6	2	42.4	988	431		-12.0	2.0	14.8	169	164	178	---
.400	24.8	2	62.0	1405	525		-6.0	0.3	21.7	176	156	168	----
.317	18.7	5.26	59.0	3220[a]	4750[a]		-9.6	1.7	20.6				
.4350	18.8	5.26	43.2	2400[a]	2450[a]		-9.7	3.0	15.1	189	175	---	165
.4410	17.6	128	39.9	87.2[d]	167.8[d]		-7.0	5.3	14.0	202	182	58	163
.3705	11.4	12.8	30.8	----	----				10.8	180	173	43	----
.3765	10.2	12.8	27.1	153[d]	159[d]				9.5	200	180	42	171
.358	6.5	23.7	19.5	106[d]	95[d]	630	-17.0	-2.85	6.85	203	185	48	161
.357	5.0	23.7	14.0	---[b]	228[d]	8390			4.90	207	Off scale	53	Off scale
.500	Dry	----	-0--	81,900[c]	186,000[c]								
.3810	Dry	----	0	202,000	350,000								

[a]Considerable quantities of water droplets were collected in flask

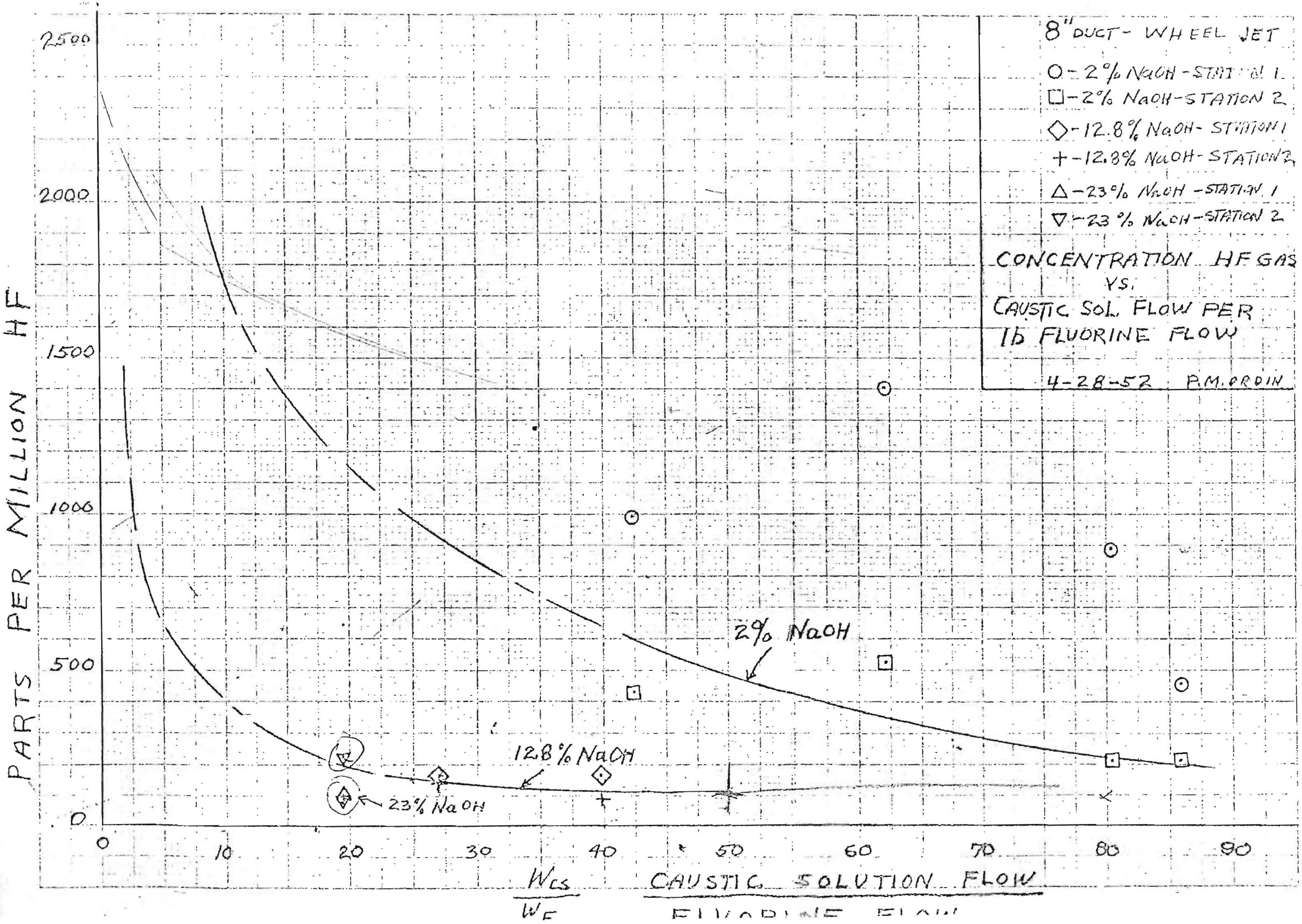
[b]Sample valve did not open

[c]Used 10 cc of 2 percent N_aOH

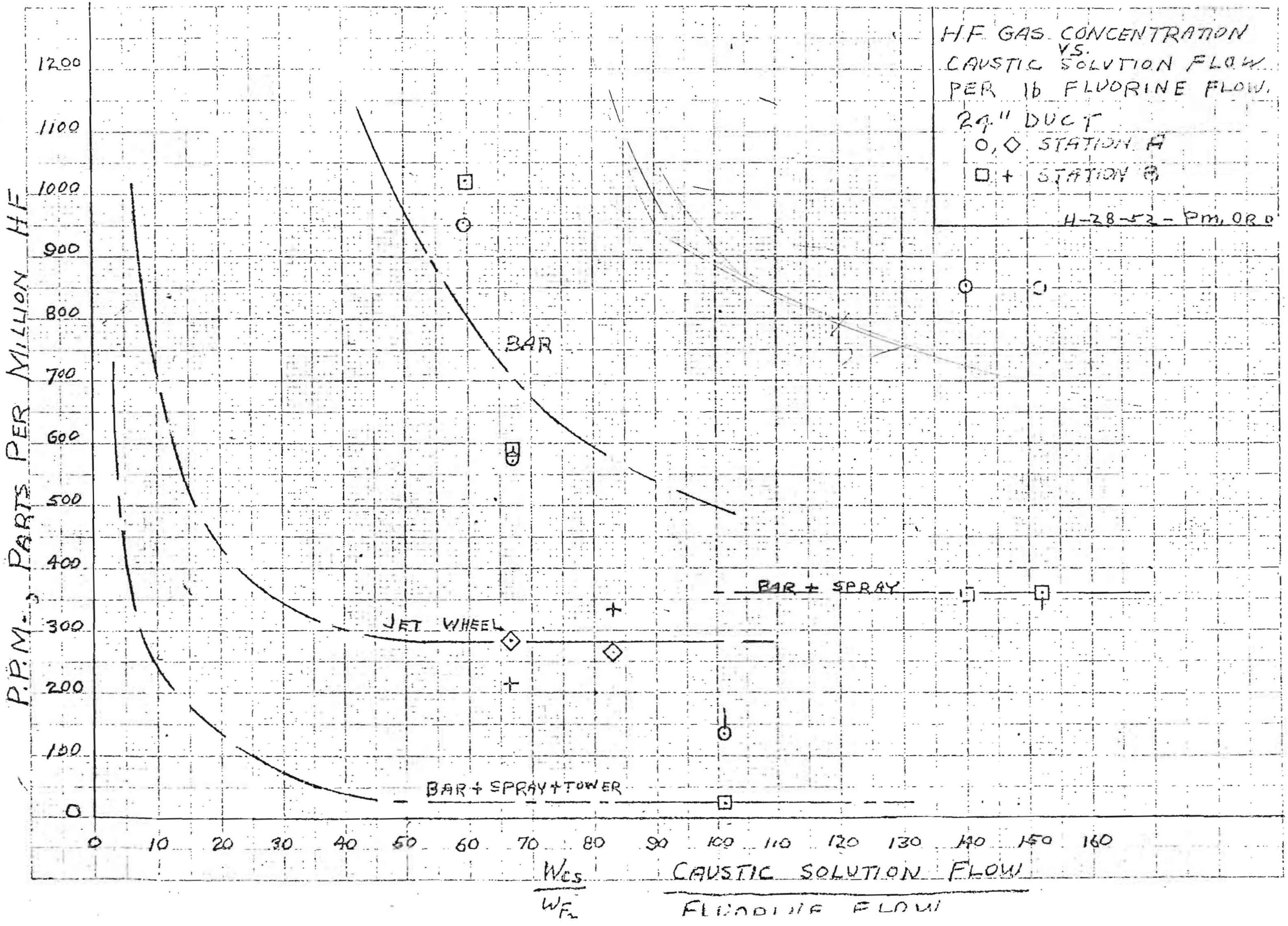
[d]Used glass wool filter



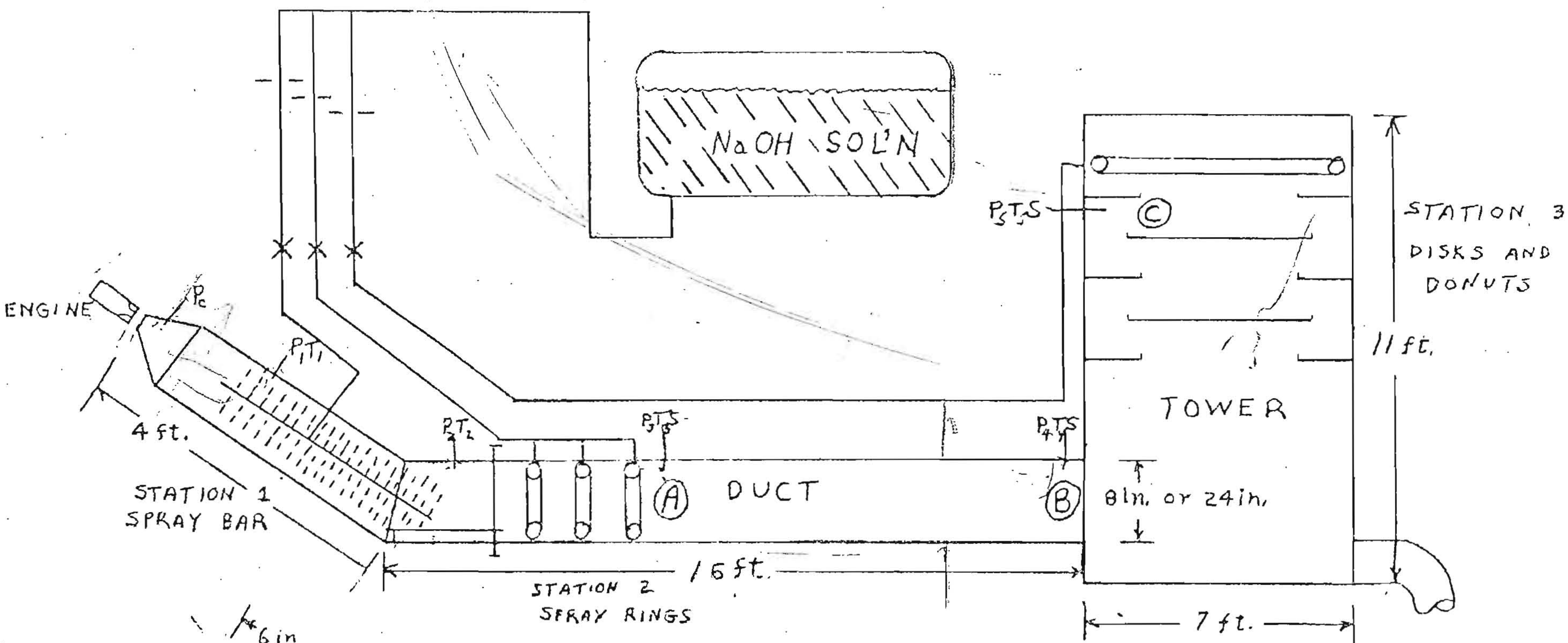
CONC. HF in PPM
vs
CAUSTIC SOLUTION FLOW
PER FLUORINE FLOW
PER UNIT AREA
4-28-52
STATION A
STATION B
STATION A - 23.7% NaOH
STATION B - 23.7% NaOH
2% NaOH
12.8% NaOH
P.P.M. HF
W/cs

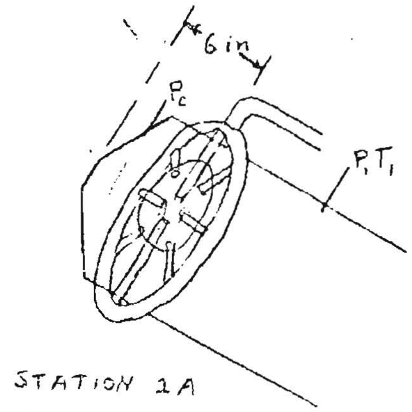


8" DUCT - WHEEL JET
○ - 2% NaOH - STATION 1
□ - 2% NaOH - STATION 2
◇ - 12.8% NaOH - STATION 1
+ - 12.8% NaOH - STATION 2
△ - 23% NaOH - STATION 1
▽ - 23% NaOH - STATION 2
CONCENTRATION HF GAS VS. CAUSTIC SOL. FLOW PER lb FLUORINE FLOW
4-28-52 P.M. ORDIN
2% NaOH
12.8% NaOH
23% NaOH
PARTS PER MILLION HF
2500
2000
1500
1000
500
0
10
20
30
40
50
60
70
80
90
W_{CS}/W_F
CAUSTIC SOLUTION FLOW / FLUORINE FLOW


H.F. GAS CONCENTRATION VS. CAUSTIC SOLUTION FLOW PER lb FLUORINE FLOW.
24" DUCT
O, ◇ STATION A
□ + STATION B
4-28-53 - PM, ORO
BAR
BAR + SPRAY
JET WHEEL
BAR + SPRAY + TOWER
P.P.M. - PARTS PER MILLION HF
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
$\frac{W_{CS}}{W_{F_2}}$ = CAUSTIC SOLUTION FLOW / FLUORINE FLOW

SCHEMATIC DIAGRAM
HF SCRUBBER





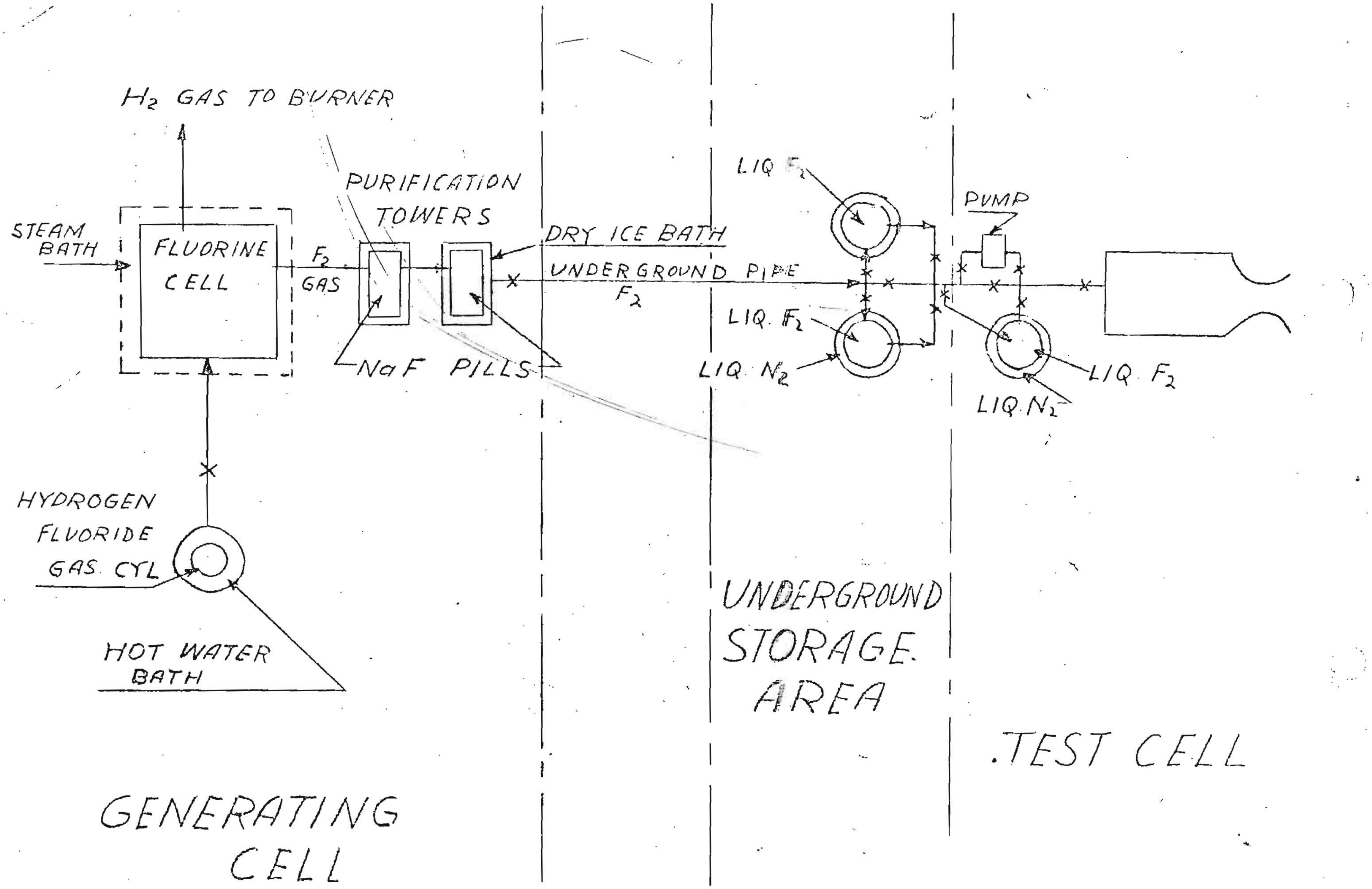
RUN CONDITIONS

A.	24 in.	DUCT,	STATION	1+2+3
B.	"	"	"	1+2
C.	"	"	"	1
D.	"	"	"	1A
E.	8 in.	"	"	1A

MEASUREMENT STATIONS

P = PRESSURE
T = TEMPERATURE
S = GAS SAMPLE

FIGURE 1



H2 GAS TO BURNER
STEAM BATH
FLUORINE CELL
F2 GAS
PURIFICATION TOWERS
DRY ICE BATH
UNDERGROUND PIPE F2
NaF PILLS
HYDROGEN FLUORIDE GAS CYL
HOT WATER BATH
LIQ F2
LIQ. F2
LIQ N2
PUMP
LIQ. F2
LIQ. N2
GENERATING CELL
UNDERGROUND STORAGE AREA
TEST CELL

FIGURE 1

Cleveland, Ohio
June 21, 1954

MEMORANDUM For Those Concerned

Subject: Considerations affecting layout of Rocket Facility at S-40 location - Drawing CDS 10308

Item No. (as indicated on drawing)

1 Operations Building - comprises offices, instrument center, control center and shop. Located to be (1) safe from test and hazardous storage areas; (2) as close as feasible to test stand to reduce cost of instrument and control lines and distance between shop and stand. Distance to test stand about 300 ft. Location of stand in valley provides natural earth protection.

2 Test Building - Located for vertical firing on natural plateau (El. 730) about 30 ft. below top grade level. Exhaust duct goes down 40 ft to (El. 690) with horizontal run at that elevation for large amounts of water spray cooling. Vertical riser used for scrubbing exhaust with outlet about 10 ft above top grade level (El. 770).

Location (a) provides natural earth barrier between test area and the operations building and storage areas; (b) requires minimum amount of excavation; (c) locates exhaust cooling at lowest elevation to make full use of water head for pumping; (d) is between airport runways to minimize height restrictions; and (e) is centered in wooded area for noise reduction advantage.

3 Auxiliary Control Room - Located adjacent to test stand for observation of cold flow testing.

4,5,6 & 7 High Pressure Gas Storage for Propellant Feed - Located close to propellant tanks to keep lines short and pressure drop low. Consist of manifolded cylinders mounted vertically to facilitate hydraulic testing. Recessed into earth bank to shield from stand.

8 Water Reservoir - Located (1) on high ground and raised about 10 foot above grade 760 to provide head for exhaust cooling; this eliminates large costly pumps; (2) as close to exhaust duct as possible to minimize length of large water feed line.

9 Exhaust Duct - See other memoranda and drawings.

10 Lime Slurry Reservoir - Slurry to be added to water-HF solution exiting from exhaust duct. Location (1) close to exhaust duct; (2) near road for filling; and (3) at height so that head serves in place of pump.

cc: Haas
Marcus
Berg
Nettleman
Friedes
on 6/23/54

11 Settling Basin - Water-HF - lime mixture from exhaust duct flows to this basin where solids settle out. Located a few feet above river bed near exhaust duct.

12 Water Catch Basin - Located at river bed level to receive filtered water from slurry settling basin for pump return to reservoir.

13 Water Return Pump - For returning water from water catch basin to reservoir.

14 Sludge Removal - Sludge to be removed from settling basin by truck when accumulation demands.

15 Helium Compressor - For compressing gas from supply trailers into storage manifolds. Located on main service road for accessibility and protection from test area. Length of line to storage manifold not critical.

16 Liquid F_2 Storage - By means of ~~transfer table~~ transportable dewars with liquid nitrogen jackets. LN_2 transportable dewar located in storage area for "make-up" quantities. Location (1) natural protection from thrust stand; (2) earth mounds isolate it from work areas;and (3) large distance from test area permissible because of transport containers. Distance from operations building about (200) ft.

17 Liquid Ozone Storage - Storage will probably be in transportable dewars. Storage area isolated by earth mounds and removed from work areas. Distance to operations building about 400 ft.

18 Liquid Oxygen Storage. - Permanent location storage tanks with transfer lines to test stand. Location (1) is protected from test area by natural earth bank; (2) on main service road for accessibility for filling; and (3) relatively close to minimize length of transfer lines to test stand.

20 High Pressure Liquid Nitrogen Pump and Evaporator - For charging gas storage from liquid supply. Located at liquid N_2 storage because of liquid pump considerations. Length of high pressure line to gas storage not critical.

19 Liquid Nitrogen Storage - Main storage area located for same reasons as item (17). Some of the tanks to be transportable for use at this location and also at the hydrogen liquefier (item 23) and fluorine storage (item 16).

21 High Pressure Liquid Oxygen Pump and Evaporator - For charging gas storage from liquid supply. Location for same reasons as (19).

22,23 Non-Hazardous Fuel Storage - Such as hydrocarbons, alcohol, and ammonia. Location (1) for easy access near main service road; (2) away from test area to eliminate necessity for protection and leave that area clear for equipment desired close to stand; and (3) length of transfer lines to propellant tanks not critical.

24 Hydrogen Liquefication and Liquid Storage - Storage in transport dewars to facilitate transfer to propellant tanks. Location (1) away from test area and normal traffic for protection; and (2) at a safe distance from other work areas.

25 Heavy Duty Roads - Must be capable of handling heavy truck traffic. Effort has been made to minimize length of these roads.

26 Test Observation Post - For direct observation of engine during tests. Would contain telescopic viewers, communication with control center, and warning or cutoff switches. Location for (1) view of the engine; (2) approx. same elevation as engine; (3) about 210 ft from test engine.

27 Further Oxidant Storage - For additional stationary oxidant storage. Location offers (1) protection from test area by earth bank; (2) accessibility on main service road; and (3) relatively short length for transfer lines to propellant tanks.

28 High Thrust Expansion - Locations along earth bank for same reasons as planned test building. Would make use of propellant storage areas and operations building.

29 Low Thrust Expansion - Probable area for any low thrust testing. Other areas more desirable for high thrust locations or adjacent to roadway.

GRK:md

George R. Kinney

C O P Y

June 21, 1954

C O P Y

Electrical Power Requirements - S-40 Rocket Facility

Present Needs:	KW
Hydrogen liquefier, compressors, 350 HP	260
High pressure water coolant pump, 300 HP	225
Jet wheel pump, 300 HP	225
Ozone generator (4.5 KW hr/lb. ozone @ 10,000-12,000 volts; est. 30 lb/hr)	135
Water reservoir return pump, 15 HP	11
Compressors (hydrogen and helium), 2 @ 25 HP, 50 HP	38
Instrument power	30
Lighting (office, shop, test cells, instrument area, control bldg)	50(est)
Power equipment (hoists, shop tools, etc)	25
Air compressor	10
Liquid nitrogen pumps	5
Ventilation motors	25
Miscellaneous transfer pumps, 15 HP	11
Refrigeration equipment	10
	1060

Possible Future Requirements:

Pump facility, 1500 HP

C O P Y

C O P Y

May 27, 1954

PRELIMINARY COST ESTIMATE - ROCKET FACILITY AT S-40

1.	Site preparation and roads	$ 140,000
2.	Extension of services - trench, H_2O, gas, steam, storm sewer, sanitary sewer, service air	145,000
3.	Electrical power	125,000
4.	Office building and shop	100,000
5.	Test stand and building	225,000
6.	Scrubber-silencer ducting, including H_2O piping, sprays, reservoirs, treatment system	300,000
7.	Pumps, motors and starters (if required) for scrubbing	(118,200)
8.	Control room and instrument building	40,000
9.	Liquid storage tanks (not incl. H_2)	105,472
10.	F_2 trailer and storage unit, 1200 l @ 33,000	33,000
11.	Propellant tanks	200,000
12.	Gas pressurization tanks	148,400
13.	High pressure piping, liquid	49,320
14.	High pressure piping, gas	29,800
15.	Low pressure piping	14,340
16.	Instrumentation	275,000
17.	Compressors for helium and hydrogen, 2 @ $40,000	80,000
18.	Material handling equipment	60,000
19.	Safety and site protection	100,000
20.	Special foundations, pits and pads	42,000
21.	Pump investigation facility	-0-
22.	High pressure H_2O system for cooling motor	8,500
		$ 2,339,032
23.	Liquid H_2 storage (incl. 2 trailers)	29,750
24.	H_2 liquefier	122,850
		$ 2,491,632

25. Above values based on 3 minute runs for all fuels except H_2. For 2 minute running time, less $128,600

NACA - Lewis

Cleveland, Ohio
September 10, 1954

MEMORANDUM For Record

Subject: Meeting held at Lewis Laboratory on September 8, 1954 to Discuss S-40 Rocket Lab Facilities

1. NACA personnel present were:

Messrs. B. G. Gulick	O. J. Luchini
D. W. Berg	Dr. L. Gibbons
D. A. Friedes	T. Reynolds
L. R. Marcus	P. M. Ordin
J. H. Nitchman	S. Deutsch
O. J. Haas	L. H. Rieman

2. The following items were discussed, and agreements reached:

(1) The Operations Building as originally shown to be a two-story office building with basement was estimated to cost $190,000. A one-story building was proposed of steel panel and steel partition construction which would cost between $145,000 and $160,000. A one-story building was agreed to be satisfactory if entry to test control room could be so arranged to discourage entrance by personnel who wished to discuss instrument problems with instrument engineers at times when they had to conduct or prepare for a test run.

(2) The rocket exhaust duct length of 28 feet is sufficient for a 100,000-pound rocket, however, a deflector plate or water basin with water nozzles shall be provided at the bottom to prevent burning out of the steel duct by the rocket flame.

(3) A future rocket cell using the No. 1 cell exhaust cooler is not to be considered in the present design.

(4) Tests have shown that water sprays of sufficient intensity will prevent or reduce the hazard of detonation, therefore, sprays are being provided. The duct thickness shall be designed for a thickness less than that needed for theoretical detonation pressure calculations.

(5) The exhaust cooler shall be designed for a temperature of 212 degrees Fahrenheit as the rocket flame temperature will be reduced to this value as a result of cooling by initial jet ring water and consequent mixing before reaching the cooler.

File for record only per L. Rieman per B. G. Gulick 11/2/54

(6) The high-pressure liquid propellant tanks shall be housed in a ventilated weatherproof and easily accessible shelter. Its location may be changed for economical design.

(7) An alternate method for fuel storage was suggested which eliminated earth mounds and reduced the required road. No decision was reached regarding the proposed arrangement but further study is to be made.

(8) The drainage of the test cell should have special treatment because fuel will be spilled in this area and will have to be treated before disposal.

(9) A reduction in test cell height from 37 feet to 20 feet was proposed with an extended or extendable area immediately over the rocket mounting. This proposed alteration will be considered.

(10) A common storage area for the high pressure gas (N_2, He, H_2) was considered satisfactory if there was no chance for charging the various cylinders with the wrong gas. The bottles were to be protected from the direct shrapnel path and need not be installed ~~in a~~ vertical ~~vault~~ below the ground level.

L. H. Rieman
Mechanical Engineer

LHR:mh
DWB
BGG

cc: B. G. Gulick
D. W. Berg
D. A. Friedes
L. R. Marcus
J. H. Nitchman
O. J. Haas
O. J. Luchini
Dr. L. Gibbons
T. Reynolds
P. M. Ordin
S. Deutsch
L. H. Reiman
J. R. Braig