Screenings
from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY
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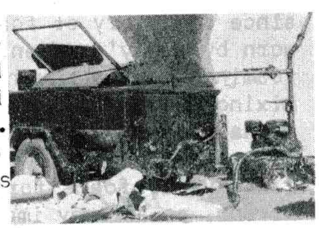
SURFACES, SUDS, AND ASPHALT

Pardon us for going soft, but suddenly the subject is asphalt, notable for its hardy tenacity, water repellancy and black-hearted stamina. It varies in consistency from a casual collegiate Goo willing to adapt itself to any smart situation, to a sophisticated shining Gunk, stiff, strong, righteous and unyielding. Fortunately the goo-to-gunk transition is readily controllable. Both have their uses.

Asphalt is a petroleum product and not to be confused with tar, with which everybody confuses it. Tar is produced from coal, gas, wood, peat, or bones; asphalt is the left over from crude oil after the naptha, gasolene, kerosene, fuel oil, etc., have been cooked out. Both tar and asphalt come under the general class bitumens. Useful tar products include creosote, phenols, napthalene, coal oil, road tar, roofing pitch, and inedible shotgun targets.



But our subject is asphalt.

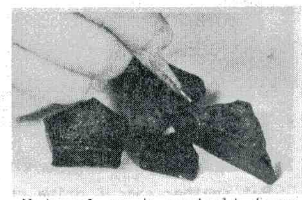
Within Mummies' Tummies

Perhaps the most inspiring use of asphalt was as a preservative in cut rate Egyptian mummies, where it assured immortality of the soul but not of Egypt. Nowadays we rely on clean living, psychoanalysis and Democrats.

About two-thirds of our asphalt goes into roads, and most of the rest goes for dry roofs. We can say with a fair degree of confidence that virtually none goes into mummies, except perhaps as a prank. (Are you absolutely sure you know everything that goes on in the Masons?) A somewhat similar use of tar, on the outside and in conjunction with feathers, has also declined in recent years, although the number of logical nominees is reported on the increase.

Black hearts and sticky feet

Already several thousand years B.C., asphalt was used in highways and water reservoirs in Messypotamia and similar garden spots. Builders used naturally occurring asphalt, produced when crude oil leaking out on the surface of the ground slowly loses its volatiles to the air. This leaves pools of asphalt and outcrops of asphalt-impregnated rock.

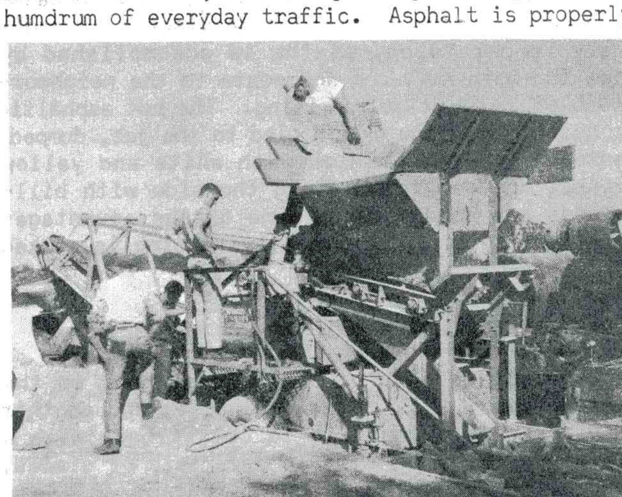


Natural rock asphalt from Kentucky--actually asphalt-impregnated sandstone.

Still, the first use of asphalt as a roadway was much earlier--prehistoric, as a matter of fact. During the Pleistocene, most notably at Rancho La Brea, near Los Angeles, quite a variety of beasts sauntered over the natural asphalt pools and failed to extract themselves before suppertime. Hence the term asphalt jungle, or in the words of Uncle Remus, some tar baby. Brer Elephant and Brer Camel, among others, got caught by the hundreds. Brer Saber-toothed Tiger and Brer Dire Wolf and other union leaders felt a vibrant twinge of social conscience and jumped in to tidy up. They of course got caught, a sort of primeval income tax. Thus was born the fearsome howl of the first Beatniks. Howls have been emerging on and off ever since, heard or not.

That old black magic called roads

The mistake of Brer Camel and other beatniks was in assuming that asphalt, which is merely an essence of life, is strong enough to support the humdrum of everyday traffic. Asphalt is properly



From such variegated heaps great asphalt roads grow. This central mix plant is adapted to use foamed asphalt, p. 3.

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But another campus drive cheaply built with foamed asphalt. "Before" photos are on pp. 3 and 5 (under the machine). Engineering Experiment Station buildings are on the right.

only the stickum for the solid particles that give life its substance, binding them together into a waterproof, cohesive mass. Asphalt is but a cement for mineral aggregates. In fact, asphalt refined and controlled for use in roads is termed <u>asphalt cement</u>, abbreviated A.C. Asphalt cements vary from soft to hard, the hardness being in part controlled by addition of a viscous flux oil. Hardness is measured by penetration with a standard needle; a large penetration indicates a soft asphalt cement.

ASPHALT + AGGREGATE

Problem I for the asphalt engineer is not the asphalt but the aggregate. Aggregate may be graded, with a wide range of particle size to give maximum packing and intergrain contact, or it may be ungraded and stuck together with an asphaltic mortar. Pardon us if we skip the details.

The best asphalt roads are built by mixing aggregate directly with asphalt cement. Because the A.C. is more than a little viscous at ordinary temperatures, mixing is accomplished by heating both A.C. and aggregate to the neighborhood of 300°F prior to mixing. The hot asphaltic concrete mix is quickly hauled to the job, dumped, spread, rolled, painted with white and yellow lines, and decorated along the side with billboards and speed traps. One of the advantages of civilization is System; everything is worked out in advance.

<u>Cutbacks and emulsions</u>

Heat is expensive, or at least heat in the neighborhood of 300°F is expensive, and another way to apply asphalt is to cut it back with a solvent. Cutbacks come in a variety of grades, depending on the kind and amount of solvent. Naptha, kerosene, and fuel oil are usual solvents, and give rapid curing, medium curing, and slow curing cutbacks, respectively. Temperature of application varies from about 50° to 275°F, depending on amount of solvent, i.e., how close the cutback is to being pure asphalt cement. For plant mixing, the aggregate is also heated. Cutbacks are extensively used for spray treatments of new or old roads.

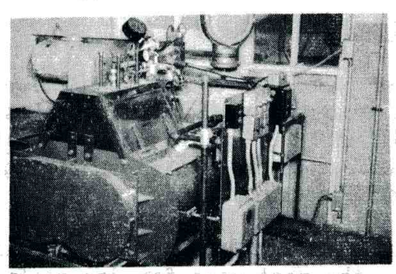
Disadvantages of cutbacks are the curing time required for volatiles to evaporate, and cost of the volatiles, which add nothing to the final road.

A third type of asphalt for roads is emulsified asphalt, a creamy black suspension, usually colloidal asphalt droplets in water. Emulsified asphalt may be applied cold and even to cold, wet aggregate. If it is properly constituted, the emulsion then breaks, water comes out and leaves the asphalt stuck on the aggregate. Problems in use are engineer fear, correct timing of the break, and what to do with the excess water. Emulsions are the ticket for small jobs or for patchwork where heating is impractical.

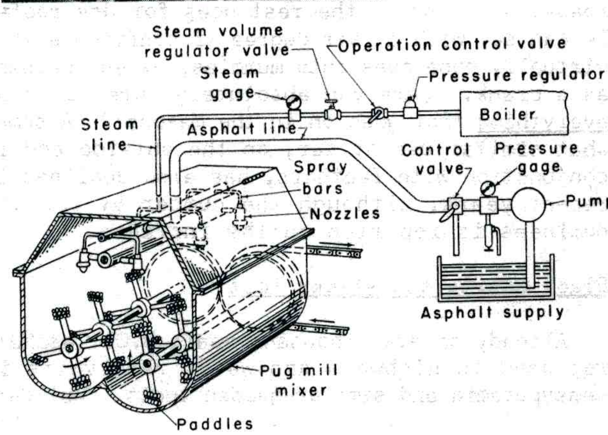
FOAMY!

So much for ordinary, run of the plant methods; now we must mention the greatest engineering lift since discovery of foam rubber life preservers worn by today's women. We refer to controlled foaming of asphalt, a new and slightly sensational mixing aid that allows low temperature mixing of asphalt cement without solvents or emulsifying.

Actually foams form a good part of today's living, as already implied. Foams put the puff



Pilot plant (where's the pilot?) for artificially foaming asphalt in pug mill mixer.



in whipped cream, the bulk in a candy bar, the glue in meringue, the bounce in a mattress, the head on a bubble bath or a beer, the wetting power in lather, the mouth watering symptoms in advanced hydrophobia. Combining these factors of bulk, tenacity, elasticity, beauty, aroma, penetration, and fear of water, asphalt foams have nevertheless been regarded as very bad.

Unexpected foaming converts a hard and healthy asphalt cement into an overflowing, vicious mass with all the perverted sensitivities of fresh bubble gum. It oozes, it flows, it penetrates, it stretches, and it sticks to everything. Special antifoaming agents have been developed to keep the asphalt kettles from foaming over and violating shoes, tempers, language, and equipment.

From such vexatious clues, evener tempers prevailed. and one day Professor Ladis H. Csanyi (Sahn´ee) of Iowa State began to wonder. Under Csanyi's direction, special foam generating equipment and nozzles were developed in the Bituminous Research Laboratory of the Iowa Engineering Experiment Station. Foamed asphalt was shot directly into mixers, and extensive laboratory and field tests disclosed a number of unsuspected advantages. Such as:

1. More even and uniform distribution of asphalt is obtained throughout the aggregate.

2. For high-type mixes, aggregate temperatures may be lowered to about 240°F.

3. For lower-type mixes, cold, damp, or wet aggregates can be successfully coated.

4. Hot mixes can be converted to cold stock pile mixes by chilling with water as the mix leaves the mixer.

5. Hot mixes may be laid on wet surfaces or even under water.

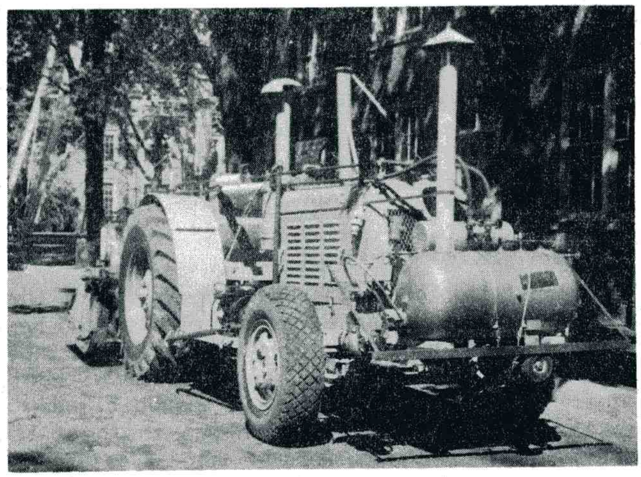
6. Wet, slurry-type seal coat mixes can be produced with asphalt cements as the binder.

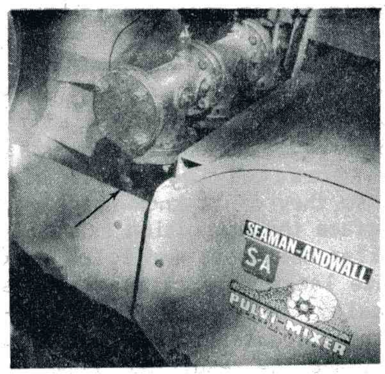
7. Ungraded local aggregates may be used in mixes.

8. Clayey, silty, or sandy soils can be stabilized in a moist condition with the foamed asphalt cement.

SHADES OF SURFACE CHEMISTRY

These lucrative benefits will sound more believable if we beat the drum and make aboriginal noises--in other words, make with the theory.





Seaman-Andwall Pulvimixer experimentally fitted for soil stabilization with foamed asphalt. That is the steam boiler on the front, complete with whistle? Mixer is at back. Photo at left shows position of nozzles.

Physical properties of foamed asphalt are quite different from those of the parent liquid. Most obvious is that the asphalt bulks up like a plump one removing her girdle; this in itself should promote wider distribution of small percentages. A somewhat closer analogy is a foam fire extinguisher, which spreads farther and is more effective than a pail of water.

Furthermore, foamed asphalt cement is temporarily softer than the non-foamed material at the same temperature. An A.C. with a penetration of 85 to 100 will have a penetration over 300 for some time after foaming because it's so full of vapor. And soft asphalts traditionally mix better. When the foam breaks, the asphalt regains its original strength and hardness.

Bubble bath

Perhaps most important of all is increased surface area from the bubbles. This brings in surface tension, or the reason for no corners on a soap bubble. Surface tension in the soap film causes it to assume a minimum area, whether in a bubble or on a small boy's hands and face. Mothers, that's why wrists, neck and ears are practically never bathed of their own accord.

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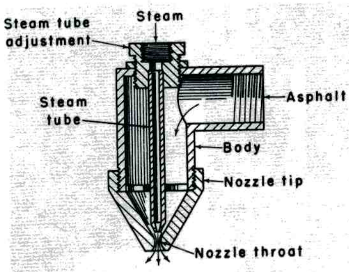


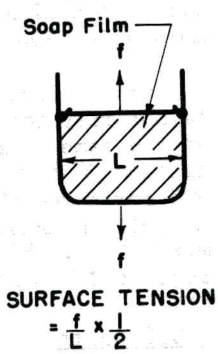
Inside a nozzle.

Manipulation of surface tension is one of the most important arts of the modern chemist and has revolutionized such chores as washing, painting, oiling, greasing, gluing, and kissing without smearing. Obviously we owe an incredible debt to the surface chemist, although the debt is being amortized by thousands of idiotic detergent ads. In fact, one could almost wish for a little less self acclaim.

And what causes surface tension? As any newspaper can tell you, tensions occur at borders patrolled by foreigners. Atoms or molecules within a mass are attracted equally in all directions, so much so they don't know which way to turn, but at a surface the attraction is mainly towards closely similar neighbors and folks back home. Though surface lacks some attractions, a close brotherhood exists between surface molecules; this clannishness creates surface tension. At a water-air interface the resulting "film" is strong enough to walk on, if you happen to be a lightweight water insect with greasy feet. Otherwise you'd better not try it.

The same clannishness exists between molecules within the mass, and will come into play as soon as you try to rip them apart and create more surface. Thus surface tension is practically synonymous with surface energy, but not quite.

Surface tension of liquids can be measured a number of ways, such as height of capillary rise in a tube or maximum size of a pendant drop before one needs a handkerchief. For illustrative purposes, consider the wire frame special deluxe soap film surface tension measurer shown at the right.



Obviously a pull, f, is required to keep the frame open due to surface tension of the soap film. Neglecting friction, the surface tension equals the force divided by the length of the wire and furthermore divided by two, because two soapy surfaces are at work, one on each side of the film.

All right, you physicists, if we pull the wires apart we do work which goes to make more surface. If we let up a bit, the soap film will do work and move the wire. To be strictly formal about this, if the wire is moved one centimeter by f dynes of force we have done f dyne-centimeters of work. There's certain poetic charm in calling a dyne-centimeter of work an <u>erg</u>.

By assuming a length l (try one-half centimeter), it's not too hard to demonstrate that surface tension in dynes per centimeter is numerically equal to surface energy in ergs per square centimeter. Well, now!

<u>Practicalities and reversibilities</u>

It is not necessary to believe all this in order to be anything but educated, so put away the puzzled look and let us philosophize.

For example, heat is required to boil water. (Some statements just have to be stupid.) But one way to look at it is that heat energy is used to break away water molecules and make new surface. A considerable amount of heat is required-about 540 calories per gram. By comparison it takes only 80 calories per gram to melt ice, and 100 calories per gram to heat ice water to boiling. Surface is expensive.

Fortunately, the expense is not for naught, because surface energy reactions are reversible. When steam condenses it gives back the 540 calories per gram and can cause a severe burn, ouch! or energize radiators on the fourth floor after the first three floors are unspeakably hot. Similarly you never see a soap bubble die slowly. It expires with a vigorous snap, due to release of its surface energy.

THE FOAM GENIE

A few more drum beats should assure you that we aren't fooling. Actually artificial foaming of asphalt is but another brilliant and masterly scheme for storing up heat. The foam contains literally acres of new surface surrounding the jillion quadseptillion bubbles of asphalt. This asphalt-vapor interface is really canned energy, waiting for Aladdin to come along with a can opener. The beauty of the arrangement is that the surface energy is released precisely when and where it does the most good--during mixing. The foam disintegrates, and the energy goes to help coat aggregate.

Therefore even cold, wet aggregates can be coated with asphalt cement. Furthermore the release of surface energy aids penetration, for

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dusts and soil particles can be individually coated, whereas mixing with liquid A.C. merely gives weak, coated balls.

Kinds of foam

By varying the pressures and adjustment of nozzles, two types of foam may be produced. "Discrete foam" contains the most surface area and consists of individual bubbles, a la Lawrence Welk. For discrete foam the steam pressure is 60 to 90 psi, and the asphalt is pumped at 50 to 80 psi. The pressures chosen govern the size and style of bubbles.

In "concentrated foam" the bubbles are joined together more like bubble bath. Steam and asphalt binder pressures may be as low as 35 psi and 20 psi (gauge pressure), respectively.

Saturated steam at these pressures contains not only the heat of vaporization, 540 calories per gram, but it is at a temperature well above 100°C. At steam pressures for discrete foam, the temperature is in the neighborhood 310° to 330°F; for concentrated foam it may be down to 280°F. Steam is used to clear the nozzles before and after foaming, so all remains neat and clean for an asphalt plant. Because of the low asphalt pressures, all that is needed to convert existing equipment is steam and nozzles.

Example 1: Asphaltic concrete

Asphaltic concrete concocted to meet Iowa Type A Specifications was sampled from an actual construction job, tested, and used as a basis for comparison. Stockpile aggregate from the same job was then heated to different temperatures and mixed with foamed asphalt.

(a) When aggregate is dried and heated according to specifications (300°F), foamed asphalt mixes perform quite as ably as those with unfoamed asphalt.

(b) Aggregate temperatures as low as 180°F still give excellent mixes, and more important, aggregate temperature is less critical. This means increased drier capacity and plant production.

(c) With aggregate at about 160°F, coating becomes incomplete. However, the Marshall stability of a 180°F mix is still 610 lb, compared to 1260 lb for the reference. With aggregate heated to 200°F the Marshall value is 700 lb. The minimum criterion is usually 500 lb.

(d) Cold, wet aggregates with 3 to 8 percent moisture were successfully coated. There is a slim suggestion here that water may help mixing!

Example 2: Ungraded aggregate mixes

Mixtures of natural fine sands heated to 350°, plus loess or limestone dust plus discrete foam, give Hubbard-Field Stability values in the neighborhood of 1500 to 2500, with some mixes going over 3000. Comparable mixes with high-pressure atomized asphalt gave values in every case lower, and averaging 500 lower. We sincerely believe such mixes could not be prepared with ordinary liquid A.C. Other engineers believe this, too.

Prof. Csanyi (left) says keep this road on the road. Asphalt kettle on the right, hooded pulverizer-mixer at rear. Prof. Bob Nady is at the helm.

Similar mixtures were prepared with concentrated foam, and results were about the same. Advantages of concentrated foam are lower foaming pressures, and the fact that aggregates needed to be heated to only 240°F.

Test road

In June, 1957, a section of a test road was constructed in Ringgold County in southern Iowa. The mix consisted of pulverized agricultural limestone heated to 300°F, plus 7% A.C. concentrated foam. Mixing was done in a Cedarapids Continuous Mix plant with the output about 140 tons per hour.

We are pleased to report the road has stood up under pounding of loaded quarry rock trucks plus 250 paltry cars per day. We might remark that subgrade soils in Ringgold County are not the best for roads, being plastic loess over Kansan till and gumbotil.

Cold test

Another test area was built with 75% fine sand and 25% loess, plus 6% A.C. concentrated foam, only this time the aggregates were not heated at all, and water was added to aid mixing!

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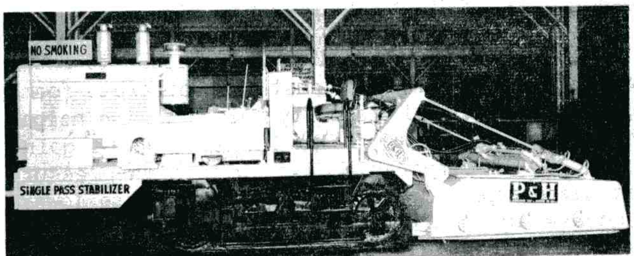

P & H Single Pass Soil Stabilizer decked out for application of foamed asphalt.

Foamed 150-to-200 penetration A.C. was shot right into the moist (8% water) soil mixture. Hubbard-Field Stability ran about 3000 at 77°F dry, 1600 to 2200 at 140°F dry, and 600 at 140°F wet. A seal coat was added to prevent scuffing.

The pavement was laid in September, 1956 and have been carrying about 250 cars a day ever since. At last look it was still there. You are welcome to drive over it and sigh.

Example 3: Soil stabilization

This last little experiment is actually soil stabilization, since soils were not heated or treated prior to mixing. Another kind of soil stabilization is with a road mixer, which chews up the existing soil, adds stabilizer, and lays it all back down in one operation. Previously soil stabilization had been tried with cutbacks and emulsions, but not with asphalt cement.

One of our lovely campus thoroughfares was selected for this experiment, the natural in-place soil being $1\frac{1}{2}$ to 2 inches of cinders on top of clay, which is actually not so lovely unless we do something about it. Six percent concentrated foam A.C. was added with a Seaman Pulvi-Mixer in several passes which were interrupted by rain, blast that weather man! A seal coat was applied to prevent scuffing.

Two test lanes were constructed and opened immediately to about 400 cars per day. That was in 1957. So far no distress, no weakening.

Now to the country! In 1957 about $\frac{1}{2}$ mile of a county gravel road was given the treatment, $5\frac{1}{2}$ percent foamed asphalt cement. Soils ranged from A-4 (3) to A-7-6 (15), or loam to heavy clay. All went well until a gruesome Spring dumped 15 inches of water in one month, and in some places the subgrade soils gave the asphalt a bit of a letdown. Repairs and resealing have kept the public faith.

Parking a lot

The latest use of foamed A.C. is a 5-acre parking lot at a new shopping center in Sioux City, NW Iowa. Advantages of the foam are evident when you see what was used for aggregate--a mixture of 65% silty loess soil plus 35% blow sand.

Foam was applied to unheated soil containing 12% moisture. Soil was picked up, coated, mixed and spread in a single pass by a P & H Soil Stabilizer moving along at 27 feet per minute. This is not bad when you consider that soil is taken in at one end and road comes out the other. The asphalt-treated soil was compacted, covered with a chip coat surfacing, and laid open to the onslaught of time, weather, and the woman driver. Currently foamed asphalt soil stabilization is being tried for Sioux City streets.

ACKNOWLEDGEMENTS AND REFERENCES SIGHTED

For further foaming see "Foamed Asphalt in Bituminous Paving Mixtures," by L. H. Csanyi, in Highway Research Board Bul. 160, 1957, and "Use of Foamed Asphalt in Soil Stabilization," by R. M. Nady and L. H. Csanyi, Hwy. Res. Bd. Proc. 37: 452-467, 1958. Also "Foamed Asphalt," in American Road Builders' Association Tech. Bul. 240, 1959.

Patents on use of foamed asphalt are licensed by the Iowa State University Research Foundation on a non-exclusive basis.

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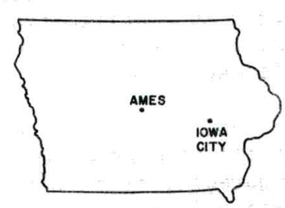
NOTE THE NEW NAME

Hello from Iowa State University; after 101 years Iowa State College is no more. The term "college" harks back to our land-grant status but does not quite describe the size or reach of our endeavors. Foreign students are particularly name conscious.



Now the obvious confusion. Iowa State University, or simply Iowa State or ISU, is located in Ames, 30 miles north of Des Moines, and features engineering, science, agriculture, vet medicine, home economics, and visits from Soviet Premier Khrushchev. The State University of Iowa, or Iowa U. or SUI, is located at Iowa City and features medicine, law, science, arts, hydraulic engineering, and trips to the Rose Bowl. We at Iowa State would like to go, too, but we can't find anybody to blow up our football.

RLH

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