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JOB _____

SHEET NO. 1 OF _____

CALCULATED BY _____ DATE _____

CHECKED BY _____ DATE _____

SCALE _____

ZEN AND THE ART OF BOAT DESIGN

BOATS ARE FUNCTIONAL OBJECTS.

THEY CAN BE PRETTY, BUT IF IT DON'T FLOAT IT AIN'T A BOAT.

ALL MOVING OBJECT DESIGNS, CARS, PLANES, WHEELCHAIRS, ROCKETS, BICYCLES AND BOATS REQUIRE DESIGN TO STRICT CONSTRAINTS

THE MARINE ENVIRONMENT AND ESPECIALLY SAIL BOAT DESIGN IS MATHEMATICALLY THE MOST CHALLENGING DESIGN ENVIRONMENT

CARS, BIKES AND WHEELCHAIRS FUNCTION ON A SOLID SURFACE - DIRT.

PLANES FUNCTION IN A SINGLE MEDIUM - AIR

ROCKETS ARE NOTHING BUT PROJECTILES AND ONCE THEY LEAVE THE ATMOSPHERE THEY DON'T EVEN ENCOUNTER DRAG.

CAR FORCES: ROAD DRAG, AIR DRAG, LIFT, STEERING, WEIGHT.

PLANE FORCES: DRAG, LIFT, STEERING, WEIGHT, THRUST

ROCKET FORCES: DRAG, THRUST, WEIGHT, STEERING.

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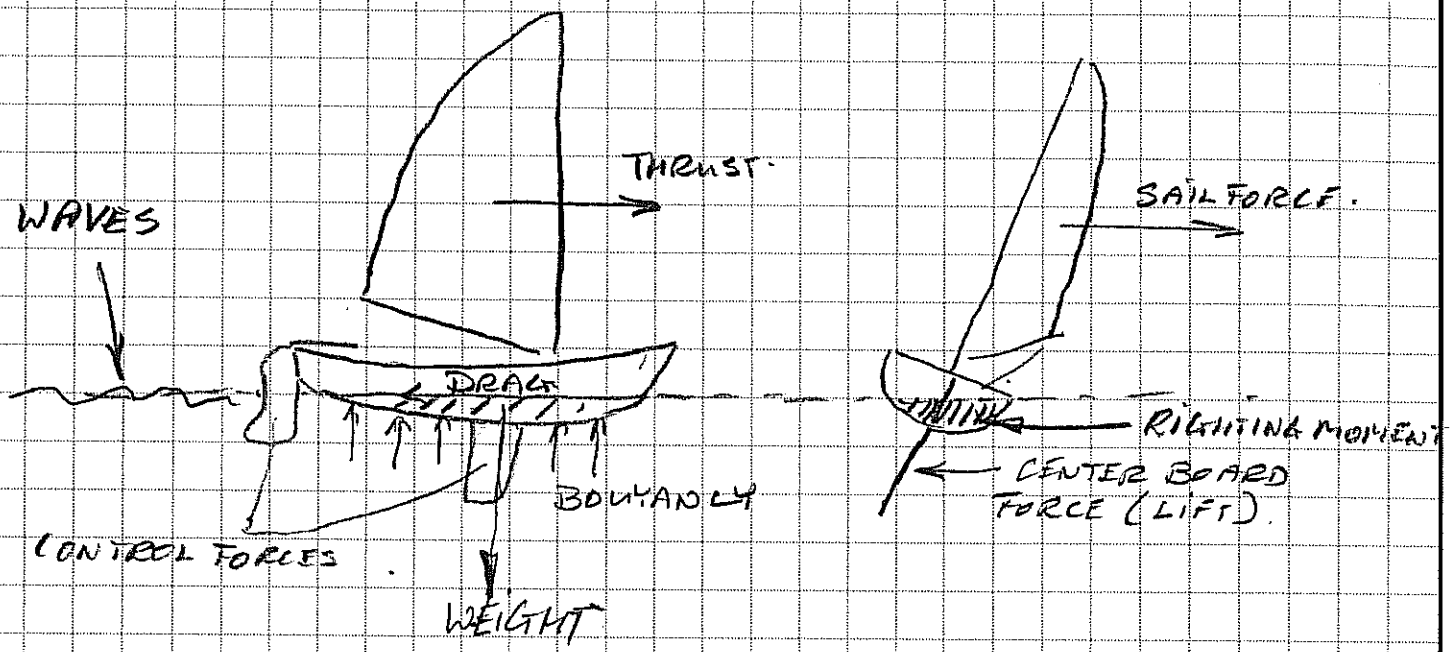
LET'S LOOK AT A SAILBOAT:



THE MATH CAN BLOW YOUR MIND. YOU HAVE TO BE SMARTER THAN A ROCKET SCIENTIST.

FORTUNATELY THE ZEN APPROACH WILL LET YOU DO A LOT WITHOUT MATH.

ALL VEHICLES ARE DESIGNED TO THESE CONSTRAINTS:

LOAD CARRYING CAPACITY
PERFORMANCE
DURABILITY

IT IS ALWAYS EASY TO GET TWO AND HARD TO GET THREE.

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SHEET NO. 3 OF

CALCULATED BY DATE

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SCALE

TO GET THREE TAKES ZEN AND MONEY.

EITHER A LOT OF ZEN AND SOME MONEY
OR LITTLE ZEN AND LOTS OF MONEY.

I HAVE LITTLE MONEY SO I NEED LOTS OF ZEN.

"FORM FOLLOWS FUNCTION"

FIND THE FUNCTION

I NEED :

I NEED A LOT.

I NEED DIFFERENT THINGS.

CAN I PUT DIFFERENT NEEDS IN ONE BOAT?

KISS

MY HOLY GRAIL IS A TRIMARAN NO BIGGER THAN 30 FEET THAT WILL SAIL FASTER THAN TRUE WINDSPEEDS AND IS SAFE TO SAIL WITH 5 PEOPLE TO BERMUDA.

LOAD CARRYING CAPACITY : HIGH, 5 PEOPLE AND GEAR ON 30 FEET.

PERFORMANCE : HIGH, 20 KNOT PLUS SAILBOAT

DURABILITY : HIGH, OCEAN CONDITIONS.

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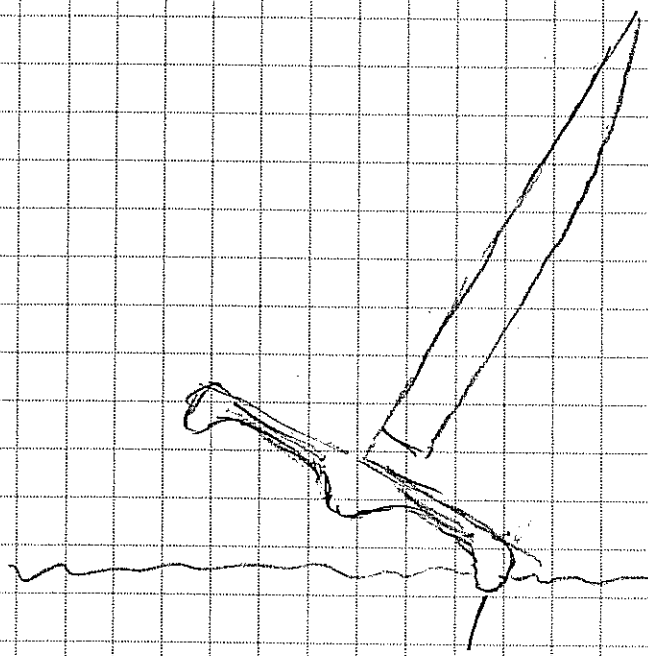
CAN IT BE DONE? YES, BUT $$$$ AND IT WILL TAKE A TON OF ROCKET SCIENTIST WITH BOAT DESIGN POST DOCTORATE TRAINING.

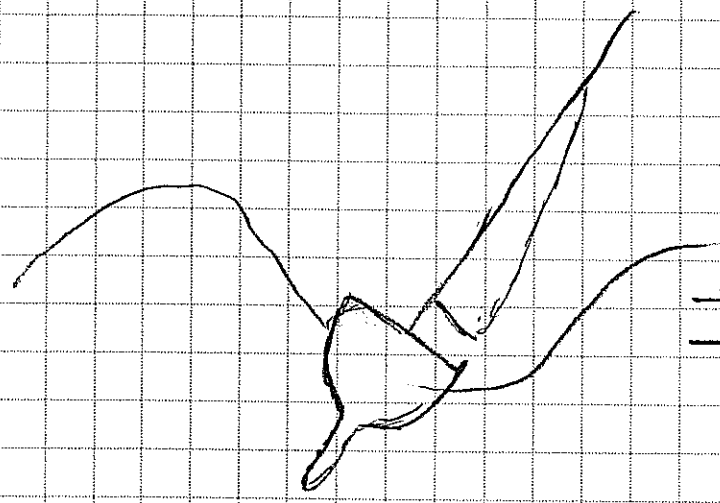
HOWEVER FOR MUCH LESS MONEY I CAN DO 2 TIMES 2 OUT OF 3, AND AS MEATLOAF SANG: TWO OUT OF THREE AIN'T BAD.



NAVESINK ROCKET.

ULTRA LIGHT WEIGHT TRI WING MAST.
COCKPIT FOR 5 WITH BEER COOLER.

→ PERFORMANCE – HIGH.
→ LOAD CARRYING – HIGH.
DURABILITY – LOW.
DON'T TAKE THIS BABY IN A CHOP.



GULFSTREAM CLUNKER.

ULTRA STRONG
SPACE FOR 5 AND GEAR.
TAKES ME TWO WEEKS TO GET TO BERMUDA, BUT I'LL MAKE IT GUARANTEED

→ PERFORMANCE – LOW
→ LOAD CARRYING – HIGH.
→ DURABILITY – HIGH.

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SO ONCE I PICK THE FUNCTION WHAT DO I DO?

YOU LET THE FORM FOLLOW.

KEEP IT AS SMALL AS POSSIBLE
KEEP IT AS LIGHT AS POSSIBLE
KEEP IT AS CHEAP AS POSSIBLE
KEEP IT AS PRETTY AS POSSIBLE.

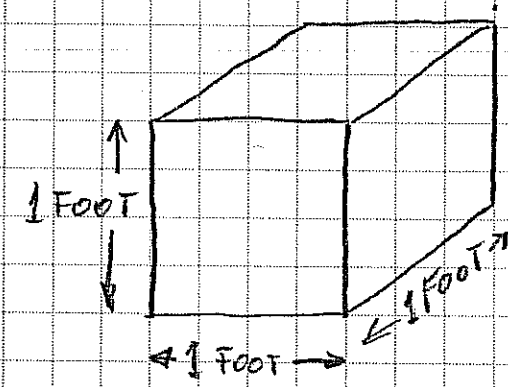
KEEP IT AS EFFICIENT AS POSSIBLE.

KEEP IT AS DURABLE AS POSSIBLE?

DESIGN IT AS FAST AS IT NEEDS TO GO - NO FASTER

A LITTLE MATH, BUT ONLY A LITTLE.

WATER WEIGHS 62.3 POUNDS PER CUBIC FOOT
SALT WATER HAS SALT DISSOLVED IN IT WHICH MAKES IT HEAVIER. SALT WATER WEIGHS 64 POUNDS PER CUBIC FOOT



A BLOCK OF WATER (FRESH)
1 FOOT ON EACH SIDE
WEIGHS 62.3 POUNDS.

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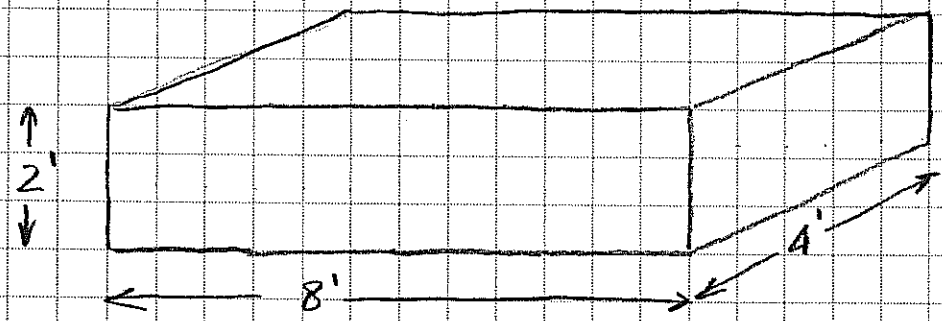
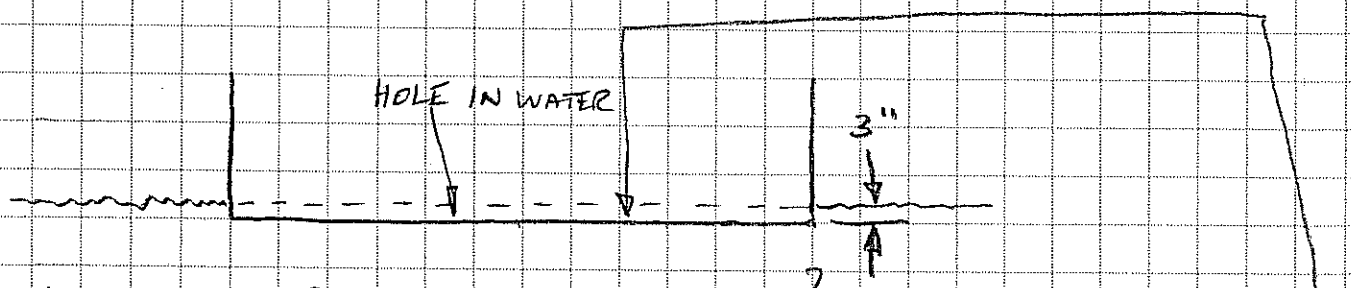
SUPPOSE I BUILD A BOAT AS FOLLOWS.:



IF I FILL IT WITH WATER WHILE IT IS SITTING IN THE BACKYARD, IT WILL HOLD 2x8x4x62.3 = 3,987 POUNDS OF WATER. — LET'S CALL IT 4000 POUNDS.
THEN I EMPTY IT AND LAUNCH MY BOAT
ONCE IT IS AFLOAT I SEE IT FLOATS WITH A DRAFT OF 3", WHICH IS 1/4 FOOT.



HOW MUCH DOES MY BOAT WEIGH?

THE BOAT'S WEIGHT IS EQUAL TO ITS "DISPLACEMENT"
THE DISPLACEMENT IS THE WEIGHT OF THE WATER "FOR THE HOLE THAT THE BOAT MAKES IN THE WATER.

HUH?

BACK TO THE PICTURE

HOW BIG IS THE HOLE?

1/4' x 8 x 4 = 8 CUBIC FEET

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HOW MUCH WOULD THIS HOLE WEIGH IF IT WERE WATER?

8 CUBIC FEET X 62.3 POUNDS PER CUBIC FOOT

ABOUT 500 POUNDS.

SO HOW MUCH DOES THE BOAT WEIGH?

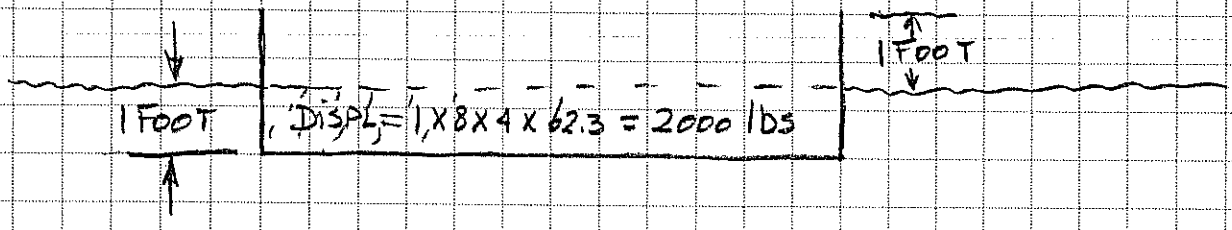
500 POUNDS.

HOW MANY PEOPLE CAN THIS BOAT CARRY?
ITS MAXIMUM DISPLACEMENT IS 4000 POUNDS
AVERAGE PERSON WEIGHT 150 POUNDS.

LET'S TRY 10 PEOPLE = 1500 POUNDS.
TOTAL WEIGHT IS THE WEIGHT OF THE BOAT PLUS THE 10 PEOPLE = 2000 POUNDS.

THAT IS HALF ITS MAXIMUM DISPLACEMENT, SO THE BOAT WILL FLOAT AT HALF ITS DEPTH.

IT WILL FLOAT AT A DRAFT OF 1 FOOT
AND IT WILL HAVE 1 FOOT TO SPARE BEFORE THE WATER COMES OVER THE TOP.



COOL: I DESIGNED A 10 MAN LIFEBOAT.

IS IT A GOOD LIFEBOAT?

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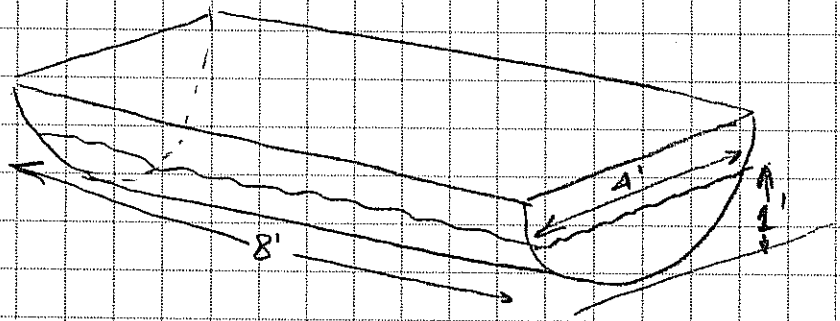
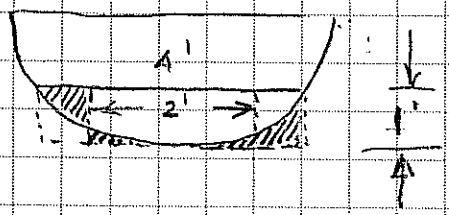
IF MY BOAT IS NOT NICE AND SQUARE I CAN STILL CALCULATE DISPLACEMENT IT IS JUST A LITTLE MORE WORK.



APPROXIMATE:



I KNOW IT IS LESS THAN 4x1x8 = 32 CUBIC FEET.
I KNOW IT IS MORE THAN 2x1x8 = 16 CUBIC FEET.
IT LOOK CLOSER TO THE LATTER
LET'S SAY 20 CUBIC x 62.3 = 1246 POUNDS.

IF THIS BOAT HAD POINTY ENDS IT WOULD BE STILL LESS DISPLACEMENT.

YOU CAN PRETTY MUCH GUESS AN 8 FOOT DINGHY CAN NOT WEIGH MUCH MORE THAN 500 lbs FULLY LOADED.

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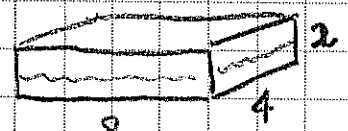
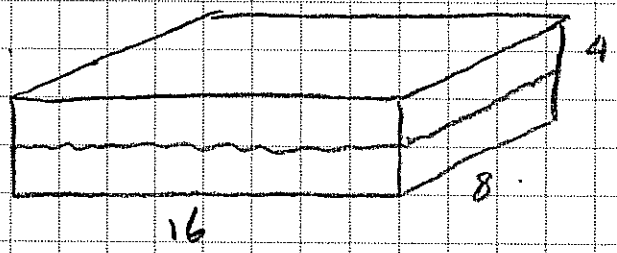
SCALE _____

SOME DESIGN RULES

- POINTY ENDS MAKE THE BOAT MOVE BETTER, BUT REDUCES LOAD CARRYING CAPACITY.
- MORE WIDTH MAKES A BOAT MORE STABLE, BUT ALSO SLOWER.
- BEAM (WIDTH) IS CHEAP.
- A LITTLE EXTRA WIDTH ADDS LITTLE COST, LITTLE WEIGHT, LOTS OF PAYLOAD AND A LOT OF STABILITY.
- IF I USE THE SAME SHAPE AND DOUBLE LENGTH, DEPTH AND WIDTH I GET 8 TIMES THE DISPLACEMENT.

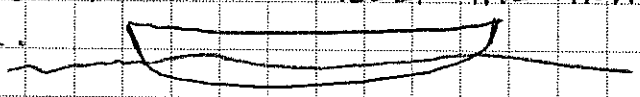


DISPL: $1 \times 4 \times 8 \times 62.3 = 2000$ lbs

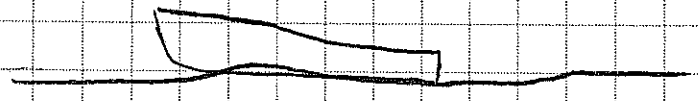


DISPL: $2 \times 8 \times 16 \times 62.3 = 16{,}000$ lbs.

- DISPLACEMENT HULLS ARE NOT PLANING HULLS.
- WITH DISPLACEMENT HULLS KEEP THE TRANSOM OUT OF THE WATER.



- PLANING HULLS NEED FLAT BOTTOMS IN THE BACK.



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SHEET NO. 10 OF _____

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SCALE _____

- WITH DISPLACEMENT HULLS DRAG CONSISTS OF FORM DRAG (NICE SMOOTH SHAPES IS GOOD) AND WETTED SURFACE AREA (SKIN FRICTION). KEEP THE WETTED SURFACE SMALL.
- TOO MUCH POWER CAN KILL A GOOD DESIGN. MORE POWER ADDS MORE WEIGHT, REQUIRES MORE FUEL, MORE WEIGHT REQUIRES MORE POWER, WHICH ADDS MORE WEIGHT, WHICH . . . . . .
- THE SAME GOES FOR SAILBOATS.
- WEIGHT IS BAD. MANAGE YOUR WEIGHT.
- THE BOAT IS ONLY AS STRONG AS ITS WEAKEST LINK.
- MAKE STRUCTURE CONTINUOUS.
- STRUCTURE THAT SERVES SOME OTHER PURPOSE IS GOOD. (THWARTS, SEATS, BULKHEADS, CABINETS)
- WOOD HAS ABOUT THE SAME DENSITY AS WATER.
- PEOPLE HAVE ABOUT THE SAME DENSITY AS WATER.
- FUEL HAS ABOUT THE SAME DENSITY AS WATER.
- FIBER GLASS HAS ABOUT TWO TIMES THE DENSITY OF WATER.
- FOOD (BEER, FISH, MEAT, FLOUR) HAS ABOUT THE SAME DENSITY AS WATER.
- METALS ARE HEAVIER

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- WOOD CAN HOLD ABOUT 2000 POUNDS PER SQUARE INCH, BUT BE SMART ABOUT THE GRAIN.
- FIBERGLASS CAN HOLD ABOUT 10,000 POUNDS PER SQUARE INCH.
- SAFETY FACTORS !!
- OPEN BOXES ARE FLEXIBLE.
- CLOSED BOXES ARE STIFF
- EPOXY IS GOOD. A GOOD EPOXY JOINT IS ABOUT AS STRONG AS THE WOOD.
- DESIGN IS APPLIED PLAGIARISM.
- DOUBLING THE SIZE OF A BOAT INCREASES THE DISPLACEMENT 8 TIMES, ITS REQUIRED STRUCTURAL WEIGHT ABOUT 4 TIMES AND ITS REQUIRED POWER TO REACH THE SAME SPEED LESS THAN 4 TIMES.
- DISPLACEMENT VESSELS CANNOT REALLY GO FASTER THAN HULL SPEED $= 1.34 \sqrt{\text{WATER LINE LENGTH (FT)}}$
  HULL SPEED IS IN KNOTS. (SORT OF MPH).
- SKINNY HULLS CAN BEAT THIS
  $\text{HULL SPEED} = \frac{L}{3b} \times \sqrt{L}$ L = WATERLINE LENGTH (FT)
  b = BEAM @ W.L. (FT).
- ALWAYS PUT THE HEAVY STUFF LOW IN THE BOAT.

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SHEET NO. 12 OF _____

CALCULATED BY _____ DATE _____

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SCALE _____

DESIGN YOUR FIRST BOAT.

1 SQUARE = 1 FOOT.

BOAT'S PURPOSE :

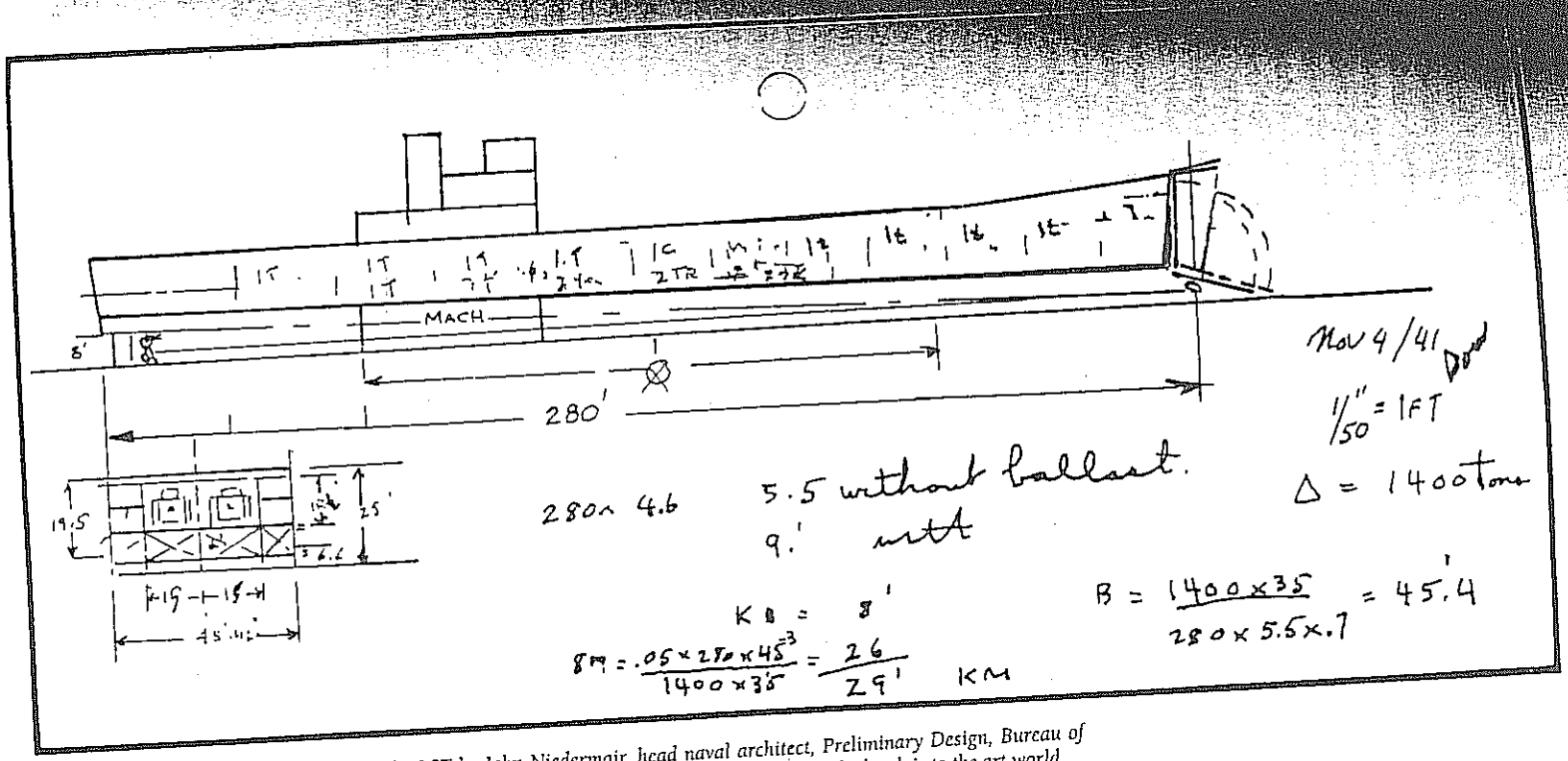

FIGURE 7-7—*Original pencil sketch of the LST by John Niedermair, head naval architect, Preliminary Design, Bureau of Ships. 4 November 1941. [Note: this sketch by Niedermair is to naval engineers what a Rembrandt sketch is to the art world. Regardless of its graphic quality, it is a classic to the engineer.]*